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ABSTRACT

The Search for Exemplary Preservice Elementary Science Programs was undertaken to recognize programs that modeled effective teaching behaviors and prepared teachers for developing appropriate attitudes and skills in students. This document describes the seven exemplary programs that were recognized by the National Science Teachers Association's Search for Excellence. The criteria for excellence are listed and explained and perspectives are offered on what was learned from the search. Programs reviewed include those from: (1) University of Toledo; (2) Ball State University; (3) University of Georgia; (4) Eastern Michigan University; (5) Utah State University; (6) Austin Peay State University (Tennessee); and (7) University of Southern Mississippi. (ML)

Focus on Excellence

Preservice Elementary Teacher Education in Science

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Foreword Preservice Elementary Teacher Education in Science

There is a crisis in science education. Advances in science and technology have transformed our lives in recent decades, and will continue to do so at an ever-increasing rate. Responsible citizenship in this democracy requires citizens who can make informed decisions on the uses of science. Yet most Americans still regard science as the province of stereotypical eccentric geniuses and wild-eyed mad scientists.

Science is not yet viewed as an integral part of either the school curriculum or our day-to-day lives. Many otherwise educated Americans are illiterate in science. Otherwise competent teachers are afraid to teach science, and students are afraid to enroll in science courses.

The root of the present crisis—and the fertile seedbed of a brighter future in science education—is the elementary teacher preparatory program. If teachers can be taught to present science in ways that reflect what we now know about the nature of science and the way children learn science, tomorrow will be brighter for their students and their students' children.

At the present time, elementary teaching students are likely to take too few courses in math and science. The courses they do take are likely to be designed for career scientists, not teaching generalists. Our search for exemplary preservice elementary science programs aimed to uncover the exceptions to this sorry situation.

Each of the seven exemplary programs described in this volume is carefully designed to focus on the science skills, knowledge, and attitudes that students need. Faculty in each program model effective teaching behaviors, and prepare teachers for creative adaptation to a dynamic future.

Students whose teachers are trained in these programs will learn with enthusiasm, and demand continued excellence in science education as they enter secondary schools. Pressure for improvement in secondary school science will result in better prepared candidates entering preservice programs—and we will all move forward with the cycle of excellence thus begun.

—John E. Penick

Chapter 1 Excellence in Preservice Elementary Teacher Education in Science

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The quality of life in our society is, and promises to continue to be, highly dependent on science and technology. Biotechnology is altering our economy and job markets through changes in agriculture, industry, and medicine. We are on the verge of breakthroughs in many areas, from cleaning up oil spills to curing major human diseases. Even now, each of us makes daily decisions that are based on science and technology. The need for scientific and technological literacy is inescapable.

Where can the American people turn to meet this need? Science educators can exercise leadership in providing the tools to cope with and make a difference in this changing world. There is a growing realization that students' attitudes towards science are formed in the elementary grades. These attitudes determine a student's capacity to learn science and understand the technology upon which our society is based.

The current national focus on science education began with attention to science in the secondary schools in 1982. As various states pushed for excellence in secondary school science, a common lament began to be heard from secondary science teachers:—"If students had decent science programs in elementary school, they would at least come to us with positive attitudes towards science, and some science skills on which we could build!"

Their cry has been heard. The national attention which focused first on secondary science is beginning to extend to the elementary schools. Some states and school districts have responded by requiring that science be taught in the elementary grades a certain number of minutes per day or per week. Others are developing and implementing district or state-wide tests to ensure that students attain basic science skills during their elementary school years.

Effective elementary science programs and effective elementary science teachers are the keys to developing appropriate attitudes and skills in students. But today science anxiety runs rampant among this country's elementary teachers. A study by Stake and Easley (1978) suggests that not even half of the nation's elementary students have a single year in which a substantial share of the curriculum is devoted to science, and the teacher does a good job of teaching it. Many teachers ignore science completely.

Science anxiety has combined with the "back to basics" movement (in which science was excluded from the basics) to inhibit progress in elementary science teaching at a time when our need for scientific and technological expertise is growing daily.

The science education community must face and conquer science anxiety. Educational institutions with teacher preparation programs must identify and propagate practices that relieve science anxiety, and provide teachers with the attitudes, skills, and knowledge to teach science effectively at the time when children's minds lend themselves most readily to inquiry, exploration, and discovery. It is easier to prepare teachers properly than it is to provide remediation once they have been certified and are teaching.

In 1981, NSTA's Steering Committee on Teacher Education, chaired by Ken Mechling, set out to gather the data for a portrait of science teacher preparation in the 1980s. Stedman and Dowling studied certification practices; Donnellan investigated elementary teachers' perceptions of their

preparation for teaching science; and Mechling inquired into program requirements in science for preservice elementary teachers. These data revealed the need to identify a desired state for preservice elementary teacher education programs and to identify practices leading to the desired state.

The certification study found serious inconsistencies among the 46 states which responded. Nineteen states require some science for early childhood certification, and 36 states require science for elementary certification. Most, however, do not identify which science courses preservice teachers are to take.

Only seven states specify even one course in biology or physical science. Presumably, preservice teachers can satisfy their requirements by taking courses with very limited classroom application, such as Famous Scientists, Food and Drugs, or Kinesiology. Moreover, only one quarter of the states demand a science methods course for elementary certification (Stedman & Dowling, 1982). Elementary teachers, science supervisors, and elementary school principals all agree that most elementary preservice training inadequately prepares teachers to teach science (Donnellan, 1982).

Mechling surveyed the 50 institutions of higher education with the largest number of teacher education graduates in the U. S. during the 1979-80 academic year. His data indicate that in half of the responding institutions preservice teachers were not required to earn any more science credits than non-science majors who were not planning to teach. Eight credits or less were considered adequate for both groups. Most institutions did not even specify disciplines in their graduation requirements for teachers. As a result, many teachers have had no preparation in either physical or Earth science, both critical subjects in the elementary curriculum.

The science courses teachers commonly take are surveys designed for non-science majors. Their only alternative is to enroll in courses designed as the first steps of series for people who intend to work in traditional science professions. In neither case is the preservice teacher likely to see any relationship betweeen the contents of these courses and the science he or she will teach in elementary school. Only one third of the responding institutions offered science courses which were specifically developed to meet the needs of prospective elementary teachers.

During 1981-1982, the Teacher Education Committee of NSTA addressed the question: What kind of science teacher preparation would produce a confident beginning teacher able to provide young children with a positive attitude toward science and relevant science content and skills? (Since elementary teacher education traditionally integrates all the subjects taught in K through 6, including science, into one comprehensive program, *science teacher preparation* here indicates those courses, learning opportunities, and experiences that prepare a person to teach elementary science, as opposed to language arts, mathematics, etc.) The committee's work culminated in the following recommended standards.

Standard 1a: Science Content Preparation

All colleges and universities should require a minimum of 12 semester hours or 18 quarter hours of laboratory or field-oriented science, including courses in each of these areas: biological science, physical science, and Earth science.

Standard Ib: Science Content Courses for Elementary Teachers

These courses should be designed specifically to serve the needs of preservice elementary school teachers. They should

- Provide knowledge of science content selected for its application to elementary school classrooms
- Increase skill in using the processes of science
- Develop positive attitudes toward science and science instruction at the elementary school level

If student enrollment does not warrant separate courses in science content for preservice elementary teachers, the required science courses should reflect the special needs of these preservice teachers.

Standard IIa: Science Teaching Methods

Preservice elementary teachers should be required to complete a minimum of one separate course of approximately three semester hours in elementary science methods. This course should be scheduled after the science content courses and just prior to student teaching.

Standard IIb: Content of the Science Teaching Methods Course

The elementary science methods course should develop instructional skills which will help preservice teachers teach science processes, attitudes, and content to children in grades K-6. The course should allow prospective teachers

- To experience hands-on activities which promote process skill development
- To select science content appropriate for the elementary school
- To design classroom environments that promote positive attitudes
- To choose and use a variety of instructional strategies and materials
- To develop techniques for evaluating pupil progress in science

Standard III: Field Experiences

Preservice elementary teachers should have opportunities throughout their undergraduate years to teach science to children in schools. These field experiences in science should begin with observation and tutoring and proceed through small and large group instruction. Student teaching must include experience in planning and teaching science.

Standard IV: Faculty Preparation

Faculty assigned to teach science content and methods courses for preservice elementary teachers should have the qualifications, experience, and interest to provide high quality instruction. They should be be instructed in science laboratories and educational facilities that include equipment, instructional materials, and library holdings which promote science learning and exemplify outstanding school science programs.

Standard V: Professional Orientation

The professional orientation of preservice elementary teachers should include experiences that

Standard V: Professional Orientation

The professional orientation of preservice elementary teachers should include experiences that

- Instill positive attitudes toward science and science teaching
- Foster an appreciation for the value of science in the total curriculum and in the lives of the children
- Develop a commitment to continue their education as teachers of science through reading, professional organizations, and further education, including inservice experiences.

It is within the context of these standards that the Association for the Education of Teachers in Science (AETS) collaborated with NSTA to institute the 1985 Search for Excellence in Preservice Elementary Teacher Education in Science. The standards were the basis for the actual criteria used in the search.

These criteria use course titles and numbers of credits that are common in higher education institutions. The number of credits indicates that a minimum amount of time is to be devoted to a specific subject. This is not intended to suggest that every institution must have a specific course for each topic with the prescribed title and number of credits. It is creativity, and not conformity, that will promote excellence in preservice education for elementary teachers. Innovative approaches to course development can produce prospective teachers who are willing and able to use appropriate pedagogical, scientific, and technological skills and knowledge in their teaching.

(Figure 1) **Criteria for Excellence in Preservice Elementary Teacher Education in Science**

In the preservice education of elementary teachers in science, the program recognized for its excellence will prepare teachers who

- Display positive attitudes toward science and science education
- Recognize the inherent value of science in the lives of all people
- Implement courses which meet the SESE criteria for elementary school science
- Seek continuing professional self-improvement in science and science teaching

With regard to background in science concepts and processes, the preservice elementary teacher's preparation will:

- Include 12 semester hours of study balanced among biology, physical science, and Earth science
- cover content specifically applicable to the elementary curriculum
- Provide understanding of the societal implications of science and technology
- Provide competence in science processes such as observing, classifying, measuring, interpreting, predicting, and experimenting

With regard to education in science teaching approaches and strategies, the preservice elementary teacher's preparation will provide the candidate with

- At least three semester hours of study, ideally undertaken just prior to student teaching
- Knowledge and skills to work effectively with a wide range of student abilities and socio-economic and ethnic backgrounds
- Personal problem-solving and process skills, acquired through significant hands-on experience
- The knowledge and skills to develop a classroom environment that promotes positive attitudes toward science
- The ability to use media, computers, and other technologies appropriately in classroom science instruction
- The ability to use a variety of instructional strategies and materials, including local/community resources and personnel
- An (understanding) of how to ensure safety in science activities
- An understanding of techniques for evaluating pupil progress which are congruent with instruction and which address the processes as well as the content of science

The candidate's instructional program will be carefully organized to provide

- Significant field and laboratory experience—at least 30 percent of the candidate's science coursework should be based on direct experience in investigating phenomena with scientific equipment
- Opportunities throughout the program to teach science to children in schools—these experiences should begin with observation and tutoring and gradually proceed through various forms of small and large group instruction
- Student teaching which includes experiences in both planning and teaching science to elementary school students
- Significant contact with the kinds of facilities, equipment, and instructional and library materials which are typical of outstanding science teaching/learning programs
- A continuous feedback process to keep the program current in both science and science education

Faculty who serve in the preservice education of elementary teachers in science should

- Have the qualifications, experience, and interest to provide high-quality instruction
- Have specific preparation in and experience with the teaching of science
- Model exemplary instructional design and practice in science teaching
- Keep current in science and science education research
- Model participation in professional associations in science education
- Maintain a close continuing association with cooperating elementary schools

These criteria may appear reasonable, even obvious and readily implemented, to those unfamiliar with the internal workings of most colleges and universities. However, to those who know the resistance to change in most traditional teacher education programs, these criteria are challenging indeed. Traditional biases and the constraints of bureaucratic functioning will confront those who promote change to meet or exceed these criteria.

The following are some of the biases that must be overcome in order to develop programs meeting these criteria for excellence:

- Scientists in some universities do not consider it appropriate to develop job-related courses for any profession other than that of research scientist, whether the job is engineering, nursing, or teaching.
- Many university scientists dislike the use of science prefixes on courses for preservice elementary teachers because they say the courses lack academic rigor. They think that proponents of special courses are asking for "watered down" versions of courses that already exist in the sequence for science majors.
- Most working scientists have little occasion to consider that elementary teachers are generalists who must be prepared to teach competently across the curriculum during a four or five year period of undergraduate education.

The following are some organizational constraints that may inhibit the development of excellent preservice elementary teacher education programs:

- Most institutions require some minimum number of students in a course, in order to pay a faculty member's salary for teaching it.
- The misconception that teaching science requires the same methods as teaching other disciplines may result in institutions requiring preservice teachers to enroll in general methods courses, rather than offering specific instruction in science methods.
- Lecture is the primary mode of instruction in traditional science courses, which focus on acquisition of the accrued body of knowledge. The processes of science and problem identification and solving are not emphasized.
- Laboratory experiences, if they exist at all, are often in separate sections of courses and may not be synchronized with the lectures. The laboratories are usually confirmation and deduction exercises, providing few chances for prospective teachers to experience open-ended inductive investigation.

Since teachers teach as they were taught, they are likely to provide an environment for children which supports curiosity, investigation, and inquiry only if they are taught in a similar environment. The lack of science teaching in elementary schools suggests that preservice elementary teachers are not able to, or not willing to, translate practices from general methods classes into methods for teaching science. These criteria call for a specific science methods course separate from general methods courses, though not necessarily separate from science content courses.

In education departments or colleges which offer separate elementary science methods courses, the need to equalize teaching loads sometimes means that non-science educators, generalists in elementary education, or even specialists in other disciplines are assigned to teach the elementary science methods courses. This is why we stress the qualifications of faculty.

There are other cautions to remember when reviewing a program for conformity to these criteria for excellence. Course titles and abstracts cannot give a comprehensive idea of what prospective teachers will learn from a program of courses. Be sure to obtain specific information when evaluating a program or a course.

The evaluation procedures used in courses are crucial to what the prospective teacher learns. Undergraduates will take what is tested as their measure of importance, rather than what a professor says is important. If the two are not commensurate, the student will behave in response to what is graded. For example, if a prospective teacher's task was practicing process skills, but testing covers only the body of scientific facts, concepts, and theories used to develop the process skills, the prospective teacher is unlikely to believe that process skills are important. One could expect to find that person teaching children only the accrued body of knowledge.

It should not come as a surprise that no institutions are identified which excel in all aspects of the criteria delineated for this search. However, the goal of the search was to identify institutions in which desired practices are being implemented. The Search for Excellence in Preservice Elementary Teacher Education in Science is a strategy for change. We believe that publicizing institutions which are successful in some areas will stimulate them to further growth, and inspire others to adopt, adapt, or generate their own versions of these practices. In this way, the search will ultimately improve the condition of elementary science teaching throughout the nation.

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Chapter 2
CBTE: An Individualized Elementary Science Teacher Education Program

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The University of Toledo is a state-supported urban institution that serves about 1.2 million persons in northwest Ohio and southeastern Michigan. The College of Education and Allied Professions has full time students in baccalaureate, masters, education specialist, and doctoral programs, with one half of the students enrolled in teacher certification programs. The Department of Elementary and Early Childhood Education prepares professionals at the early childhood, elementary, middle, and junior high school levels. Our 150 students, including those who have an area of specialization in science, work with 17 department faculty in the interdisciplinary undergraduate Competency Based Teacher Education Program (CBTE).

Design of the Program

Preservice elementary science teacher education at the University of Toledo is an integral part of the Undergraduate CBTE Program. The program was designed in 1968–1969; implementation began in 1970; and by 1973 the College operated a fully developed CBTE program. The program represents a single, comprehensive effort to bring about change in the way elementary and secondary teachers are prepared for teaching. Corresponding changes have occurred in the schools where these graduates are most likely to teach. The premise that changes in teacher education should also change the schools has led to a working agreement among university and public and private school personnel to educate preservice and inservice teachers at the same time.

Our enhanced teacher education program is practical, exacting, and flexible. It is field based, so students learn about teaching in actual classrooms. The broad goals of education are clearly articulated, so that success is easy to demonstrate. The University of Toledo's teacher education program specifies the knowledge, skills, attitudes, and values needed by teachers, but allows alternative means and varying lengths of time for achieving these specifications. Together, members of the college faculty and local school personnel have created a school-based curriculum for teacher education which respects the uniqueness of learners by individualizing the instructional process. Each teacher education student meets common educational objectives, but each does not meet them in the same manner or time frame. Science education at the University of Toledo has been unique in these respects.

Goals and Objectives

The developers of the University of Toledo's CBTE program adopted a statement of ten broad goals of teacher education. Each teacher is prepared to employ teacher behaviors which will help every child

- Acquire the greatest possible understanding of him/herself and appreciation of his/her worth as a member of society
- Develop an understanding and appreciation of persons belonging to different social, cultural, and ethnic groups
- Master basic skills in the use of words and numbers
- Exhibit a positive attitude toward school and toward the learning process

- Acquire habits and attitudes associated with responsible citizenship
- Acquire good health habits and an understanding of the conditions necessary for physical and emotional well-being
- Receive opportunity and encouragement to be creative in one or more fields of endeavor
- Understand the opportunities open to preparing for a productive life and how to take full advantage of these opportunities
- Understand and appreciate human achievement in the natural sciences, the social sciences, the humanities, and the arts
- Prepare for a world of rapid change which demands continuing education throughout adult life

Objectives were prepared for each of the ten program goals in five contexts. The objectives, broadly stated in terms of behaviors which can be observed and measured, lie at the heart of the CBTE program. Each objective tells the teacher-in-training what is expected as a demonstration of having mastered the skills it requires. The objectives are also the backbone of the instructional modules. A single module consists of one or more objectives, a rationale, suggested instructional activities, materials to be used, and evaluation procedures.

The professional education program at the University of Toledo involves three career decisions courses, four block courses for elementary education students, and a full quarter of student teaching. All courses are accompanied by clinical and field-based experiences which include teaching youngsters in local schools. These early experiences add up to 300 hours of field-based teaching over three years. Student teaching, done in the senior year, comprises another 300 hours of teaching experience.

One of the blocks is Elementary Teaching and Learning III: Teaching Science in the Elementary Classroom. Today, the elementary science education program includes science and science education in general studies, the professional sequence, and work in areas of specialization.

General Studies Component

All students in the program complete a general studies component that provides a firm liberal education foundation and specialized content and process skills. This component of the curriculum is fully integrated and consistent with the general goals of the undergraduate teacher education program.

The general education component is important to the graduates' long term success in working with youngsters in schools, for it provides a basic understanding of both science content and teaching skills. In general studies science classes students obtain the fundamental experiences, skills, and insights they expect to develop later in their own students. Minimum requirements in science for undergraduate elementary education students include courses in biology, natural sciences, and geology. In addition to these general courses, teacher education students should graduate with

- An understanding of the central concepts, structures, and processes of one of the physical or natural sciences
- Knowledge of the ways in which a specific science discipline has influenced human achievement
- Skills of scientific inquiry in a selected physical or natural science discipline
- Refined skills of observing, recording, classifying, organizing, and interpreting phenomena unique to the selected science discipline
- An attitude of scientific objectivity when observing and evaluating data in their physical and natural environments
- An understanding of the necessity of an ecologically balanced environment
- An appreciation of the benefits society has received from scientific experimentation in general

The Professional Sequence

The principal focus in the preparation of elementary science teachers occurs in the eight quarter-hour professional block course, Elementary Teaching and Learning III. This course includes various on-campus sessions and a minimum of fifty quarter hours of related field experience in a school setting. Modules in the interdisciplinary science education course include instruction in

- Unit Planning and Implementation in Science Teaching
- Teaching Science in the Elementary School
- Critiquing and Improving Faulty Test Items in Science
- Classroom Management Techniques in Science
- Problem Solving in Science
- Concept Lessons in Science
- Inquiry Teaching in Science
- Questioning Lessons in Science

Unit Planning and Implementation in Science Teaching

A. Each student will be able to design a science unit plan which meets criteria established on the Unit Planning checklist. Components of the unit include:

- Rationale and goal statements
- Behavioral objectives
- Concept statements (science content outline)
- Pre- and post-instructional strategies and activities
- Assessment of pupil learning
- Evaluation of the science instructional system

B. Each student will be able to design daily lesson plans which are consistent with the overall unit plan and with module requirements for lesson plans in inquiry, questioning, and concept teaching in science.

C. Each student will select, prepare, and use instructional materials that are consistent with daily lesson plans and the overall unit plan.

D. Each student will be able to implement daily lesson plans that meet predetermined criteria and include the following components:

- Rationale, goals, and objectives
- Pre-assessment of pupil learning
- Instructional strategies and activities for learning
- Post-assessment of pupil learning

E. Each student will be able systematically to collect, analyze, and interpret data on the effectiveness of units which meet criteria stated on the science unit implementation checklist.

F. Each student will make appropriate revisions in the science unit plan, based on the evaluation data and criteria of the science unit planning checklist.

G. Each student will be able to function as a full, collaborating member of a two-person instructional team in the planning, implementation, evaluation, and revision of an instructional unit, according to criteria stated on the team member checklist and the personal and professional fitness checklist.

Teaching Science in the Elementary School

As a result of this experience, the prospective elementary school teacher of science will accomplish all of the following:

A. Complete the Richard Moore Science Attitude Inventory (SAI) Pretest and Posttest

B. Complete the State of Ohio Eighth Grade Science Content Pretest and Posttest, with a minimum of 80 percent science content mastery

C. Construct an interdisciplinary elementary science unit of instruction following the unit format used in student teaching (The science unit includes components of the student teaching unit, a daily master plan outline with appropriate bridges and self-evaluation sections, and one lesson plan per teaching day following a lesson plan format.)

D. Prepare a videotaped microteaching peer presentation of at least one science concept, employing one of the following four instructional strategies: divergent inquiry, convergent inquiry, questioning, or concept teaching

E. Prepare and teach at least two science activities appropriate for science learning centers in the field

F. Review and evaluate at least one computer software program that can be used in teaching in the field

G. Successfully complete the teaching of at least 16 elementary science lessons to children in the field (The student will supply a lesson plan and checklist to the observer, teach the lesson, having children manipulate concrete science materials at least 50 percent of the time; complete the self-evaluation section of the checklist, and return it to the observer upon completion.)

H. Choose and complete at least two elementary science project activities from Chapter 8, "My Mini Book of Science Activities" in the text *Creative Hands-On Science Experiences* (DeBruin, 1980) or from field experience activity in the schools (These activities are to be written, duplicated for each member of the class, and presented during the science fair at the end of the quarter.)

I. Complete all assigned readings from *Science and Children*, *Science Activities*, the text, and other pertinent sources

J. Attend class regularly and promptly (especially important because of the laboratory orientation of the class)

Test Items in Science

Given ten examples of faulty test items in a variety of formats (including multiple choice, true/false, matching, completion, short answer, and essay items), and using this module, each student will identify all test construction errors and rewrite those faulty items in the same item format. At least nine of the ten items need to be in corrected form, according to the criteria in this module, with no major test construction errors remaining.

Classroom Management Techniques in Science

A. Each student will implement positive social reinforcers during the first two weeks of field experience and meet the criteria specified on the positive reinforcement, ignoring inappropriate behaviors, and avoiding criticism checklist.

B. Given a simulated problem, each student will role play, using reality therapy with a partner, giving evidence of all of the eight components specified in the handout Reality Therapy. Each student will turn in a written script following the role-playing with all components labeled correctly.

C. Given a videotaped teaching segment, each student will become familiar with and use the positive reinforcement, ignoring inappropriate behaviors, and avoiding criticism checklist. Each student will write at least three examples of the Premack Principle, at least one of which is applicable to an elementary science setting.

Problem Solving in Science

The student develops an understanding of the process of problem solving in science and applies that process to problems in science education. Given a set of hypothetical circumstances or an opportunity to experience real or simulated problems, the student analyzes the experiences and lists the effects of rigidity, inflexibility, impulsivity, failure to identify the problem, and failure to organize information as possible barriers in problem solving efforts.

A. Given appropriate information, the student must organize the information correctly to solve the problem and list at least five steps in the problem solving process in appropriate sequence.

B. Each student works cooperatively with other interns to provide acceptable solutions to several given problems, and works independently to solve another set of simple problems.

Concept Lessons in Science

A. Given materials and a field placement, the student will design and implement a science concept lesson, giving evidence of the six relevant components and meeting criteria on the concept lesson checklist in this module.

B. Given ten statements of concept definitions, attributes, and examples, the student will match each with its most appropriate descriptor, with a minimum accuracy of 80 percent.

C. Given ten statements involving referent definition and its use in teaching, the cone of learning experiences, and the order of components in teaching a concept lesson, the student will match each with its most appropriate descriptor with a minimum accuracy of 80 percent.

D. Given seven examples of segments of a concept lesson, the student will label each with its component name with no more than one error.

Inquiry Teaching in Science

A. In an actual classroom situation, each student will teach a lesson using Suchman's methods for convergent inquiry in science. These include

- The rules and purposes of inquiry
- Pre-assessment
- Student inquiry
- Student and/or teacher summaries
- A follow-up analysis of the more effective questions for subsequent inquiry sessions

Each student will receive a cooperative peer evaluation

averaging 3.5 or higher on the inquiry lessons group evaluation form and/or on the instructor's evaluation of specified criteria on the convergent inquiry self-evaluation form.
B. Having completed objective A above, each student, in an actual classroom situation, will teach a lesson expanding upon the inquiry process and making it more inductive. This technique is known as divergent inquiry. The student will demonstrate ability as a planner, introducer, questioner, and sustainer of inquiry; a rephraser; and a value investigator. The student will receive a cooperative peer evaluation of 3.5 or higher on the expanded inquiry lesson group evaluation form and/or the instructor's evaluation of specified criteria on the divergent inquiry lesson self-evaluation form, items 1–7.

Questioning Lessons in Science
A. The student will understand how to design and implement a science questioning lesson and incorporate recall, convergent, divergent, and value questions.
B. The student will use all four types of questions in a written science lesson plan. In the questioning lesson, there must be at least twice as many convergent, divergent, and evaluative (higher order) questions as there are cognitive memory (recall, or lower order) questions, with at least two examples of each type. Furthermore, each question or set of questions must be labeled according to type, such as recall, convergent, divergent, and evaluative. This lesson plan and the unit plan must be approved before implementation in the field.
C. In a 7–15 minute time period during field experience, the student will teach a questioning lesson that meets the stated criteria on the science questioning observation checklist.

Field, Laboratory and Clinical Experiences

Most undergraduate laboratory experiences take place in local off-campus settings. These formal, organized, course-related field activities begin early in each student's program and continue in a sequential manner from the freshman/sophomore career decisions courses through the upper division block courses. University faculty serve as liaison persons between the school and the college (DeBruin, 1978).

Laboratory experiences may be associated with general professional education courses which all students in a given program must complete, or they may occur in conjunction with elective courses for students who seek special certification or who are pursuing special interests in education and allied professions. The major purposes in providing continuous laboratory experiences are to enable students to mesh theory with practice and to help students to reflect on and evaluate their own personal qualifications as future educators. Therefore, we choose a wide range of sites which will provide richly diverse field placements at all course levels. Before student teaching begins, each of our elementary science education students has already had an opportunity to work with children from urban, surburban, and/or rural settings, and with children from minority and non-minority groups. We also try to provide experience with handicapped children or adults, either in a special or a mainstreamed class.

Over the past five years, the actual number and diversity of field assignments per student has increased significantly, as mandated by the Ohio Standards for Colleges or Universities Preparing Teachers Edb-303-02, "Curriculum" (1983).

Clinical experiences occur in on-campus classes, seminar sessions, and unit labs, and at off-campus sites. Unlike typical classroom experiences, in which students are confronted with situations as they arise spontaneously, clinical laboratory activities are preplanned and regulated so that all students can participate in similar educational experiences under relatively controlled conditions. Clinical experiences insure that students experience typical classroom problems before they embark on in-school field experiences. Clinical experiences may also be used to reenact situations that already have occurred in the field. These experiences include role playing, peer teaching, developing and using educational media, microteaching, observing and evaluating videotaped mini-lessons, developing and/or administering and evaluating tests, participating in simulation activities, and improvising specific activities to be taught to youngsters in the schools.

Areas of Specialization

Every elementary education major selects an area of specialization from one of five academic fields or completes a second major in special education. A minimum of 20 hours of coursework in science is necessary to develop a science area of specialization. In addition to a variety of courses offered in the College of Arts and Sciences, special teacher education courses include Environmental Concepts, Physical Science Concepts, Earth and Space Science Concepts, and Biological Science Concepts. Each of the required courses covers science concepts and processes, science teaching strategies, and classroom, laboratory, and field experience opportunities.

Modules in the science education block are taught by interdisciplinary teaching teams of regular faculty from Educational Psychology, Curriculum and Methodology, Educational Media and Technology, and Social Foundations of Education. The teams spend out of class time each week to plan various class sessions. A block course usually meets three hours a day, four days a week, including scheduled clinical and field-based experience in the schools. Each interdisciplinary faculty team elects a team leader who meets regularly with other team leaders and college administrators to solve day-to-day logistical and administrative problems and to evaluate the effectiveness of team plans and the program in general.

Science instruction in the professional sequence and the science area of specialization is directed by faculty members in science education. The science education faculty work closely with members of the College of Arts and Sciences to articulate the science instruction featured in the general component of the program with their own instruction in the professional component of the program.

Program Evaluation

Prior to the 1979–80 academic year, funds were allocated to develop an internal system for monitoring all students in elementary and secondary certification programs. A ques-

tionnaire was developed and used as part of a follow-up study of elementary school teachers. During the 1979–80 academic year, a form was devised and used to follow up on our secondary school teachers. The college continues to refine procedures to follow up its graduates in the teacher education program who are employed at both the elementary and secondary levels. In a CBTE program, evaluation is an important aspect of the total teacher education process. Modules are refined when data dictate a change. Thus, the program uses both summative and formative methods of evaluation.

Observations using high and low inference instruments are completed on all student teachers to assess their teaching competencies and to determine whether the competencies taught in the program are being demonstrated in the classroom. A preliminary report of this activity is found in the monograph "Research and evaluation in teacher education: A concern for competent, effective teachers" (Dickson & Wiersma, 1980), in *Empirical measurement of teacher performance* (Dickson & Wiersma, 1984), and in DeBruin, 1983.

Attitudes Toward Science and Science Teaching

Pretests and posttests of undergraduate student attitudes toward science and science teaching have been administered quarterly since 1975. As reported by DeBruin in Piper's *Attitudes toward science: Investigations* (1977), initial study of results found greater change in attitude relative to science teaching than to science. The longitudinal study is currently in its eleventh year, and results of the first ten years will soon be submitted for publication.

The central thesis of this study is that the process undergraduates go through in solving on-campus and field-based teaching problems and the degree to which they experience success in solving these problems affects their attitudes toward science and science teaching. If undergraduates experience success in their early teaching situations they develop a positive attitude toward science and science teaching. The converse may also be true: unsuccessful experiences may lead to negative attitudes.

During the planning phase of instruction a 70-item science attitude inventory entitled "What Is Your Attitude Toward Science and Science Teaching," by Richard W. Moore (1970), is administered to the undergraduate students. The inventory is also given at the conclusion of the quarter to note any change in attitude toward science and science teaching. We have recently completed the thirty-first successive quarter of collecting and analyzing data with this instrument. In each quarter, over three-fourths of the subjects have reflected positive changes (pre/post) in attitude toward science.

The mean scores from pretest to posttest for attitudes toward science and attitudes toward science teaching increase as students move through our program. It should be emphasized that results from the first and ensuing years of the study were consistent with different groups of students. Attitude improvement has been evident in every group.

Our plans for future research will focus on isolating field-based success factors from factors operating on campus. To accomplish this, the attitude inventory will be administered prior to and immediately following field experience. Once field-based variables are identified and isolated, additional factors and the frequency of these factors will be noted for further study. Tape recordings of seminar debriefing sessions may contribute to this study.

Mastery of Science Content

Beginning in the fall quarter of 1981, a science content test developed by a panel of Ohio science educators was administered to all university students taking Teaching Science in the Elementary School. This science content test was developed for use with eighth grade students as part of the Ohio Educational Assessment Program (1979), designed to identify statewide learner needs for selected subject areas and grade levels. To insure that undergraduate elementary education students at the University of Toledo mastered at least eighth grade science content, the test was made part of the course's core requirements. A criterion level of 80 percent was required for completion of the course. Approximately 90 percent of the university students passed the test, and the other 10 percent engaged in further science activity to meet minimum requirements. A status report featuring the results of this four-year study is currently being written.

Program Needs and Plans for Improvement of the Program

Despite its exemplary citations by NCATE and NSTA, members of the University of Toledo's elementary science teacher education program have identified areas that need refinement and further needs to be met in the program's continuing emphasis on excellence. First, the monitoring of all aspects of the program needs to continue. Second, there is a need for a complete follow-up study of undergraduate science teacher education students, especially those with science areas of concentration. The staff will continue to study the progress made by its graduates and will vigorously recruit experienced teachers and graduates of the program to further their studies in master's and doctoral degree programs with an emphasis on science education. Third, as the program continues to grow in status, additional teachers who are familiar with the program need to be identified as master teachers under whom current undergraduates may teach. This will insure continuity with local school personnel and further strengthen existing relationships.

Other program needs include the following:

- Additional personnel, financial support, and science materials from international, national, state, and local sources
- Expanded physical facilities to accomodate growing enrollment
- More computers to keep pace with technological advancements
- Further clinical facilities, such as an additional microteaching center and various labs in which undergraduates could teach demonstration science lessons
- Expanded ties with local business and industrial centers whose staff would be willing to act as science mentors for teachers conducting scientific research
- Retired scientists to work with undergraduate and graduate students in the science education center
- Highly qualified high school science students who will pursue science teaching in the elementary and middle schools

- Additional graduate students to assist in teaching and become involved in further program developments
- Outreach to faculty members not yet involved with the program, e.g., members of the College of Arts and Sciences and the College of Pharmacy, to work closely with science education personnel from the College of Education and Allied Professions Joint programs need to be developed which feature cooperative use of faculty and resources.

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Chapter 3 ASK: A Four-year Teacher Preparation Program

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Graduates of Ball State University's teacher preparation program in elementary education can say without hesitation that they are prepared to teach science to children.

Ball State students attend classes on a 9<6-acre residential campus in Muncie, Indiana, a city with a population of 80,000 which provides industry and services for the surrounding agricultural area. In addition to serving as the international headquarters of Ball Corporation, which has grown into a leading space technology manufacturer, Muncie houses major automotive-related plants.

We draw students from across the country and around the globe, but many of the university's 17,000 students hail from the communities and farmlands of north central Indiana. Many students represent the first generation of their families to attend college. While students may enroll in one of six colleges, Ball State has distinguished itself in teacher education since its founding as a state institution in 1918. It has received awards of excellence from the National Council for the Accreditation of Teacher Education for the EXEL Program, the Teachers of the Disadvantaged Program, and the Multi-Cultural Education Program. It ranks first in the country in the number of bachelors and masters of arts in education degrees awarded annually.

Our program makes use of a number of university facilities, including well-equipped science teaching laboratories and classrooms; Burris Laboratory School, a K-12 public school which attracts 750 students from varied backgrounds; three preschool facilities; Bracken Library, which houses over one million volumes and contains a special educational resource collection of teaching materials and children's literature; Christy Woods Arboretum and greenhouse; a planetarium; an observatory; and an official United States Weather Station. Additionally, students have laboratory experiences in classrooms of local public schools throughout the state.

The Beginnings

Our preservice science program was very limited until, in the early 1970s, three strands were woven together as the basis of the current program. One strand was the process-oriented science approach modelled by the early SAPA, SCIS, and ESS materials. This transformed the methods classes. At the same time, innovators in the science departments and elementary education were exploring integrated approaches to scientific problem solving and saw the need for additional science laboratory and field experiences. These considerations led to revision of science course offerings to make them more laboratory-oriented and expansion of tailored course offerings from the departments of biology, chemistry, natural resources, geology, health sciences, nutrition, and geography.

The third strand was development of EXEL. Faculty in Teachers College felt a need to help students integrate and translate the knowledge from their university courses into practical, effective teaching experiences. The EXEL program recruited highly capable high school graduates who wanted to teach. The program called for students to have two quarters of practicum experience in an elementary classroom each year. In addition, the selected students would take courses in a block so that, for example, social studies

subject matter could be used to complement science, and vice versa.

These three strands—process-oriented science, integration of scientific knowledge from a number of disciplines, and the EXEL model of extensive preservice classroom experience—led to the current preservice science program. The state of Indiana modelled much of its 1977 teacher certification program on the Ball State plan.

Creative, resourceful, enthusiastic, and talented faculty from across the campus have been willing to spend their time and energy to design, develop, implement, evaluate, and revise our program on a continuous basis. Sometimes the process is formal, and at other times informal and experimental. The university governance system regulates adoption and review of major changes, while course improvements are handled informally. Task forces, committees, and small groups of energetic faculty continue to create new ideas and options. This process can work at other institutions with a desire for growth and excellence.

Program Goals

We can summarize the science competence we want for our preservice teachers in an acronym—ASK. ASK stands for Attitudes, Skills, and Knowledge: scientific attitudes, science process skills, and scientific knowledge. Science has at its source the asking of questions, and teachers who train at Ball State do more asking of leading questions than direct telling of answers.

The attitude component is extremely important. If we stimulate the curiosity of our preservice teachers, give them the joy of trying their wings in their own investigations, guide them through inductive and deductive risk-taking in a relatively safe environment, invite them to discover wonders in the ordinary, and reward their persistence, they learn science, and look forward to opening the same doors for their own students.

The scientific skills, interpreted broadly, include such learned processes as observing, measuring, identifying problems real to the student, and proposing and testing possible solutions. An emphasis on attitudes and skills implies that our courses must go beyond textbooks to active science.

The knowledge component of ASK means that students need to develop concepts and principles which will help them make sense out of their environment. Because real world problems require information from biology and physical science as well as Earth/space science, students should study basic concepts from each realm.

The major goal of preservice elementary teacher education in science at Ball State University is to produce teachers who

- Have mastered basic science knowledge and process skills so that they are able to teach science well, have confidence in their ability, and look forward to learning more science themselves
- Firmly believe that science is intrinsic to the goals of the elementary school, and therefore have a commitment to teach science
- Understand the role of classroom science in enhancing the cognitive, social, and moral development of children
- Use a variety of teaching strategies effectively in arranging concrete science experiences for children, and match content and strategies to the development level of individual children

Subjects Covered

Preservice teachers complete at least 22 quarter hours of science work, plus a science methods class. During each of the four years they also participate in a fully supervised practicum course in an elementary school setting in which they observe and participate in science teaching. Each year during this school experience students spend progressively more assigned time in the schools and assume more and more responsibility. At each level they have specific science teaching assignments. They begin working with small groups of children in the freshman year. Full-fledged student teaching occurs in the senior year.

A number of nonscience courses also include science activities or integrate science concepts with other curriculum areas. For example, the language arts course uses science lessons as a basis for the language experience activity approach. The creativity course demonstrates the development of concepts such as "sandness," (the qualities of sand) and uses science activities as a springboard for creative thought.

About 14 percent of the elementary education majors at Ball State seek licensing for grades K–3. The science methods course, Teaching Science in the Early Childhood and Primary Grades, meets their specific needs. Students enrolled in early childhood education (pre-kindergarten) also take this special class in science methods for young children.

Close to 40 percent of our education students participate in the EXEL program. These students, selected as freshmen, demonstrate excellent academic performance and commitment to teaching before and during their work at Ball State. Unlike other Ball State Elementary Education majors, they participate in supervised teaching field experiences not once, but twice, each year. They also have the opportunity to do part of this internship in British infant schools.

The EXEL coursework is carefully blocked and coordinated with school practicums so that students experience the integration of disparate disciplines in the classroom. For instance, a student might see how a population study proposed in the 2 o'clock social studies methods class can be combined with a sampling technique demonstrated in the 3 o'clock science methods class, to make a fascinating concrete investigation for her fifth graders at 10 the next morning.

Obtaining an elementary science endorsement of 32 hours is a way for preservice students to gain additional depth in science. Students may select from a variety of science courses. A number of these, such as Map Reading for Teachers, Preparation of Materials to Teach Physical Science, and Sound and Light, are specially designed for elementary teaching majors.

Pattern of Science-related Coursework Suggested for Students Seeking K-6 Endorsement

Freshman Year

- Biological Concepts for Teachers*—4 qtr. hrs., 40 percent lab

- Physical Geography/Earth Science Concepts for Teachers*—4 hrs., 25 percent lab
- Nutrition—3 hrs.

Plus at least one of the following:

- Field and Classroom Experiences in Biology for Teachers* —3 hrs., 33 percent lab
- Astronomy Materials for the Teacher*—3 hrs., 33 percent lab
- Conservation for Teachers*—3 hrs., 33 percent lab
- Elements of Human Health—3 hrs.
- Global Geography for Teachers*—3 hrs.

Experience in the Elementary School:

- Introduction to Teaching: Seminar and Laboratory*—4 hrs. (observing and tutoring children from a variety of cultural and ethnic backgrounds)

Sophomore Year

- Physical Science Concepts for Teachers*—4 hrs., 25 percent lab

Experience in the Elementary School:

- Introduction to Elementary School Classroom Organization and Management*—2-4 hrs. (observation, tutoring, small group instruction)

Courses with Components Directly Related to Science Teaching:

- Human Growth and Development*—4 hrs.
- Introduction to Exceptional Children*—4 hrs.
- Sensory Awareness and Response to Music*—4 hrs.
- Creative Experiences for Young Children*—4 hrs.

Junior Year

- Teaching of Science in the Elementary School*—3 hrs., 70 percent hands-on (includes assignments teaching children)

Experience in the Elementary School:

- Principles of Teaching and Classroom Management: Elementary School*—4 hrs. (small and large group instruction; students teach sets of lessons from each curriculum area, including science; stresses use of instructional media and materials)

Courses with Components Directly Related to Science Teaching:

- Educational Psychology: Tests and Measurements—4 hrs.
- The Teaching of Language Arts in the Lower Elementary Grades*—3 hrs.

Senior Year

- School Health Practices*—4 hrs. (includes materials for teaching health)

Experience in the Elementary School:

- Student Teaching*—14 hrs. (students teach science and other subject areas)

Courses with Components Directly Related to Science Teaching:

- Computer Literacy in the Elementary School Classroom*—2 hrs.
- Discipline and Classroom Management*—4 hrs.
- Materials and Techniques for Teaching Children of Multiethnic Backgrounds*—4 hrs.
- Teaching Reading in the Elementary School*—4 hrs.

*Courses marked with an asterisk are specifically designed for elementary teaching majors.

Content Courses

Science courses are taught in the departments of biology, geography, health sciences, natural resources, and physics. Most of these courses are designed specifically for future elementary school teachers. This does not by any means imply that they are watered down versions of more exacting courses. Instead, it means that the courses have been tailored, in collaboration with the department of elementary education, to provide content and skills which are basic to scientific literacy and which are applicable to the elementary science curriculum.

Furthermore, the courses generally are taught by faculty who have certification credentials and who have, in addition to subject matter expertise, a background in science methods, well-honed teaching skills, a genuine enthusiasm for working with preservice teachers, and continuing contacts with the elementary schools.

The chart also shows that a substantial portion of in-class time for the science classes is devoted to field and laboratory experiences during which students practice processes such as observing, classifying, measuring, collecting data, and drawing conclusions. Because the size of the science classes is usually limited to 24, students can receive individualized attention.

During several of the science courses, students explore graphic examples of the societal implications of science and technology. For instance, the physical science faculty presents the awesome power of the atom, and then challenges students to make ethical decisions about efforts to harness nuclear energy. In the geography/Earth science courses, as well as in the natural resources offerings, students delve into the concepts of spaceship earth, population crisis, and conservation of food, water, and air quality. Natural resources classes investigate local land and energy use. Biology classes visit the local water treatment facilities.

Science Methods Class

The science methods class generally comes in the junior year, after most of the other science requirements, and often runs concurrently with the 4-hour school participation course. This means that approaches and materials can be applied immediately to real children in a real classroom setting. The class precedes the senior year student teaching. Students earn three credit hours.

The methods instructor models effective science teaching strategies—from the creation of a classroom environment that promotes positive attitudes toward science, to small-group investigation, questioning, discussion, use of instructional media, role playing, recording data, building models, and brainstorming. In each case, students are involved in an activity from a student's point of view and then discuss the structure and purposes of the activity from a teacher's point of view.

The first day of class we always do some interactive science, something that students leave the room thinking about in a positive way. For instance, students love to be amazed at the large number of pennies which a seemingly full glass of water can hold without spilling. The first day also demonstrates how students can work in small groups, needing just a brief question to get them started, with very simple materials, and how from this they acquire scientific attitudes, skills, and knowledge.

Since a specific room is dedicated to science education classes, we can begin immediately to set up long-term projects that are left out on counters or windowsills, and which each group of students checks as soon as they arrive each day. College juniors are as eager as second graders to see if their bean seeds or crystals or mealworms have grown.

The course is about 70 percent hands-on science. During the first half of the course, the instructor arranges most of the investigations. During the second half, students peer teach, directly experiencing a wide range of concepts, skills, and strategies.

Typical discussion questions after an investigation are: Was this something truly worthwhile to teach children? Why? What safety precautions were or should have been taken? How could the distribution of materials have been handled more efficiently? How else could we have approached this topic? What skills do students need in order to do this activity? Would you teach this to a preoperational child? How could we tell if students have accomplished the objective?

Thus, sensitivity to safety, the ability to facilitate positive science experiences, and the ability to evaluate student progress on process skills develop from concrete experience. Students also practice and experience a variety of instructional strategies.

Our science courses strongly support the focus on handling materials and equipment which students receive in the methods course. The biology courses stress laboratory skills. The physics and astronomy courses teach students how to plan a good program with "science on a shoestring" sorts of materials. The physics department sells students a practical and inexpensive science kit, which they regularly use for teaching. The physics offering also deals with the physics of toys, which students find entertaining as well as useful in instructing students.

A major theme of the methods class is that, although we cannot learn every interesting way to approach every concept or skill, we can identify major sources of information about science and science teaching and learn how to use them. Many students leave Ball State as members of the Hoosier Association of Science Teachers, NSTA, or CESI. Our students gain firsthand experience with community resources and personnel through field trips in the science courses, projects in science methods class, and excursions with their participation classes to places such as the planetarium, a dairy farm, the Indianapolis Zoo, the Indianapolis Children's Museum, the Muncie Children's Museum, or the Ball State weather station and television/radio station. Through the methods class, students attend the state science teachers convention, assist with after-school science classes at the YW/YMCA, and serve as science fair judges.

Students in the methods class often recognize differences in Piagetian levels of functioning for the first time in the Piaget-style interviews they conduct with children of differing abilities and backgrounds. We analyze science activities in terms of the operations which they may teach or require. We also examine the development of levels of understanding causality, as, for example, in observing flotation. We discuss grouping and regrouping students for science teaching, as is commonly done for reading.

During this course, and during the formal participation course, students are required to teach science lessons at Burris Laboratory School or in the Muncie Public Schools, where they must adapt to wide ranges of ability and socioeconomic and ethnic background. They also participate in overnight camping with elementary students and have work at a day care center for disadvantaged children. This course builds upon material introduced in the reading courses, as well as in the course Materials and Techniques for Teaching Children of Multiethnic Backgrounds.

Several courses contribute to the ability of students to use media, computers, and other technologies appropriately in science instruction. This is a major focus of the formal junior participation experience. Every classroom in which our students are placed contains its own microcomputer and science software unless the school has a bank of micros. The elementary faculty at Burris School has been very active in using the computer to teach science. The Burris teachers and Ball State participants also bring classes to the Ball State physics department to use its computer bank. The methods course now requires students to run and critique several software packages. We encourage enrollment in the elective course, Computer Literacy in the Elementary School Classroom.

Role of the Teacher and the Student

The role of the teacher in this preservice elementary science education program is multifaceted, but its foremost component is modeling excellent science teaching. In order to do this, each teacher keeps current in a field of expertise by reading, attending professional meetings, conducting research, and conferring with colleagues. The teachers also participate in professional science education organizations, read the science education research, and remain abreast of conditions in elementary schools through ongoing contact with the schools. The teacher continues to grow professionally and to maintain enthusiasm for the students and the field of study. The teacher is also a primary content resource for the preservice student.

The role of the student is to become the best possible teacher of children. To do this, students need to develop excellent teaching skills, but they must also learn to know themselves, as they assume the responsibility of developing their scientific, intellectual, and interpersonal capabilities to the fullest.

Evaluation

Of Students

Evaluation of students is done by the faculty and by the students themselves. Science courses such as Biological Concepts for Teachers provide feedback to students on their laboratory performance, manipulative skills, and problem solving, as well as on content mastery.

In the science methods class, every student provides a written critique to every other student on the lessons taught in class. After teaching lessons to children, the methods students critique their own performance, which has often been taped, and has also received feedback from the instructor. The ability to plan highly motivating, valid science lessons and to recognize appropriate use of techniques is also evaluated. Students are expected to apply information discussed in class. We stress writing skills, and

look for their application in lesson plans and reports of students' assigned experiences with children.

Ball State faculty and elementary teachers who supervise our students in their work with children observe and meet regularly with students to record progress and make suggestions. The elementary education department maintains individual student development folders in which the progress of each student is tracked from freshman through senior year.

Faculty members submit faculty alert reports on any students who may benefit from special advisement and counseling regarding their professional skills, knowledge, speech patterns, or performance.

Of Courses and the Program

Students evaluate courses each quarter on forms provided either by faculty members or by the university education center. The Teacher Preparation Council, a faculty governance board, conducts a first year teacher evaluation of all recent graduates each year. This includes employer opinions and self-evaluation by the teaching graduates. Both before and after graduation, students consistently note the following strengths of our program: excellent faculty and instruction, useful application of theory to practice, positive attitudes and motivation, valuable curriculum and instructional materials, increase in knowledge, and excellent teaching assignments.

Faculty regularly measure our program against research data and successful models described in the literature.

Achievements

Placement bureau reports indicate that 87 percent of our elementary education graduates have found teaching jobs, in spite of a tight job market. Because of the quality of our graduates, Ball State University is a major exporter of teachers to other states in the Midwest and the rest of the country.

A visitor to our program would see our students actually engaging children in science and doing a good job of it, as measured by the children's obvious interest and increase in knowledge and skills, and our students' growth in planning and management skills, creative expression, and self-confidence. It is not uncommon for both our students and their supervisors to say that their science lessons are the most successful lessons they have taught. Many say that of all their professional courses they enjoy science the most. Students often comment that their participation in class investigations has taught them to enjoy science and made them more confident about their personal problem solving skills.

We hear reports such as, "The child actually cried because she was scheduled to go to the gifted and talented room during science time!" Student teachers are proud of the excellent, creative lesson plans they produce, and the response their lessons earn from pupils. When a visitor asks, "What science have you been doing?" the children's excited and involved replies tell the whole story.

Keeping the Program Healthy

The ASK program has a number of unique strengths. Eliminating any of them would threaten progress.

- Students have practical experience with science in the elementary classroom every year beginning in the freshman year. The experiences in the elementary school begin early and are continuous, allowing students to steadily gain confidence and skills. Classroom experiences are supervised by the classroom teacher and the university professor.
- As a result of our early success with the EXEL program, courses are blocked together and faculty demonstrate integration of information in teaching. Hence science activities are used to develop language arts skills, science resource books become valuable materials for reading lessons, recording scientific observations becomes an opportunity to utilize new handwriting skills, and problem solving skills help overcome geography problems. Our teacher education majors turn theory into practice and concepts into activities.
- Students receive continuous evaluation and feedback along with diagnostic suggestions to promote growth.
- This is a cooperative program which pools the expertise of faculty members from the College of Sciences and Humanities and their peers from Teachers College. A Science and Mathematics Advisory Resource Team, representing these two groups, facilitates communication.
- Faculty members who teach the science methods courses are members of science departments and teach in the science discipline as well. Thus they remain current in science and they maintain contacts with the elementary schools.
- The content of science courses is designed specifically for preservice elementary school teachers.
- Students are able to gain additional depth in science by obtaining a specifically tailored science teaching endorsement of 32 hours.
- Faculty who teach in the program have established a tradition of continuing service to the public schools and to science education, and are committed to maintaining a high level of leadership. For instance, Dr. Mim Ballou is a past president of CESI and past secretary, board member, and national convention chairperson of NSTA. Dr. Jon Hendrix, Dr. James Watson, and Mrs. Nancy Watson have contributed papers to NSTA and conducted inservice workshops for many years. Dr. Susan M. Johnson chairs the Youth Activities Committee of the Indiana Academy of Science, is a science textbook author, and works extensively with teachers. Drs. Ballou and Johnson have developed a model elementary science program with the Fort Wayne, Indiana Community Schools.
- The experienced and innovative teachers at Burris Laboratory School, a K-12 institution operated by Ball State, make it an excellent facility for teacher training and educational research.
- We experiment with small modifications every time a course is taught, so the program is alive and responsive.

Ideas for the Future

It is always enjoyable to dream about possibilities. Our dreams include the development of

- A summer science camp where children, teachers in training, and university faculty could promote the science competence of children and teachers
- A science seminar series which would bring scientists and

science educators to our campus for 1-2 week periods of intensive work with students, practicing teachers, and facul .

- A science education center which would provide statewide leadership and resources for science education
- A science stimulation program to encourage classroom teachers to come to Ball State and be "refueled" to enrich their science programs during a 6-9 week sabbatical. When the teachers went back to their classrooms, Ball State faculty would be available to assist them with implementation of their new ideas
- Learning/teaching support teams of university students and faculty who would work for blocks of time in settings needing their services to develop the science knowledge, attitudes, processes, and skills of inservice teachers

We know that dreams can become reality. We've seen it happen with ASK.

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Chapter 4 Early Childhood and Middle Grades Science Programs

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Elementary education at the University of Georgia is divided into two distinct programs, the Early Childhood Program for grades K through 4, and the Middle Grades Program for grades 4 through 8. Each is an outgrowth of certification requirements in the state. The State of Georgia revamped its certification program in the mid-1970s, providing, instead of elementary (grades K–8) and secondary (grades 7–12), early childhood (grades K–4), middle grades (grades 4–8), and secondary (grades 7–12) certificates. Early childhood and middle grades programs maintain a strong focus on field-based teacher education. Students are placed into schools the first quarter of their junior year, with the time spent in the schools increasing each quarter until student teaching, when the full quarter is spent in the schools. What follows are separate descriptions of the early childhood and the middle grades programs at the University of Georgia.

Early Childhood Teacher Education

The Early Childhood Preservice Program is a four quarter sequence in which each quarter has a distinct purpose and builds sequentially on those before. Courses are selected and planned to contribute to the overall goals for each particular quarter.The four quarters are focused as follows:
I. The professional decision—guiding the interns to understand the teaching responsibility and their feelings about it
II. Creative and effective teaching/learning encounters—planning individual lessons for one child or small groups
III. Building curriculum—developing sequential lessons over longer periods of time and with more children
IV. Intensive internship—achieving a co-equal status with the teacher

In addition to overall goals, the program identifies various roles a teacher must learn and experience in a preservice program. We focus on five important aspects of teacher activity:

- The teacher as a custodian of children
- The teacher as a diagnostician
- The teacher as a tutor
- The teacher as a manager of learning groups
- The teacher as curriculum developer or planner

Although there is some overlap each quarter, the roles are explored as shown in the chart below. (An *a* stands for a major emphasis, a *b* for a minor one.)

	Quarter			
Teaching Role	**I**	**II**	**III**	**IV**
Custodian	a	a	b	a
Diagnostician	a	a	b	
Tutor	b	a	b	
Manager		b	a	a
Planner		a	a	a

The first quarter introduces the intern to the community and the roles of the individuals in that community, leading toward the professional decision—"Do I really want to teach?" To bring that basic decision into focus, each intern spends two weeks in the school, observing the school community, but paying particular attention to the responsibilities of the teacher. The intern also studies and practices communication skills with children and peers, and iden-

tifies cultural and developmental differences among the children.

During Quarter II the intern, as the tutor/planner, plans individual lessons prescribed by the classroom teacher or college instructor. Interns teach lessons to peers on campus to demonstrate a model before using it with students in the public schools. They learn and practice a variety of teaching models, such as role playing, concept teaching, and discovery lessons. While in the public school classroom the interns also study interactions between teachers and students. The purpose of intern activities during the second quarter is to create an effective teacher/learner encounter focusing on skills appropriate in a tutorial setting.

Quarter III interns develop skills in planning curriculum and delivering these planned lessons to larger groups of children over longer periods than on level II. At this level managing skills are emphasized, as the intern begins to take more responsibility for group instruction.

The fourth quarter is an intensive internship. Students complete special teaching assignments during their first two weeks in the schools. As the term goes on, the interns' teaching efforts are monitored by school and university faculty using state-developed performance assessment instruments.

The Early Childhood Science Program

Philosophy of the Program

The program for the preparation of early childhood science teachers recognizes the teacher's need for definite competencies, and provides experiences designed to develop these competencies. The prospective teacher is given opportunities to learn science skills, to examine the philosophy and methodology of teaching science, and to demonstrate developing teaching competence. The program emphasizes the goals and values unique to science in relation to the total elementary school program. The preservice program also reflects the prospective teacher's need for a broad liberal education.

Science Content Courses

A unique feature of the University of Georgia science education program is the special set of science courses designed for undergraduate students preparing to enter the early childhood and middle grades programs. Students who enter the early childhood science program in their junior year have already completed the 20 quarter hours of science and mathematics required by the state. Most have taken 15 hours of science, 10 of which included labs, in special sections which provide potential teachers with both the content and the process of science, as well as appropriate models for instruction. These courses have limited enrollments and are taught by faculty in the science departments as well as science education faculty. Biology and geology are the most popular offerings.

The Science Teaching Course

Early childhood preservice teachers sign up for their first science methods course in the first quarter of the four quarter sequence. The performance objectives of this course have been written to take advantage of its early placement. Each competence has been identified in three ways: as a knowledge or behavior to be acquired in the classroom, as a behavior to be evidenced in peer teaching, and as a behavior to be used in teaching children. These objectives are arranged under four headings: instructional planning, the nature of elementary school science, teaching strategies and tactics, and classroom management skills.

The course is taught by five faculty members in the department of science education. While teaching styles vary, all subscribe to the same general goals and cooperatively identify the objectives to be covered in the course. They cover the *what* as well as the *how* of teaching. The nature of the course can be seen most clearly, however, in the types of activities students perform.

Peer Teaching Assignments

Students are assigned a science topic to plan for and then teach to a group of peers. This teaching session is generally videotaped and later analyzed with the instructor, using a system of interaction analysis. Further along in the course the students are again videotaped teaching a lesson. The two sessions are compared for evidence of improvement in teaching competence. The Department of Science Education has its own video classrooms designed specifically for recording and playback.

Computer Assignments

Students are expected to develop a "user" level of computer literacy in hands-on experience with a personal computer. Students learn what is available in elementary science software by critically reviewing a selection of programs in the Center for Educational Technology (CET). The CET, located on the same floor as the department of science education, houses enough computers to allow students all the time they wish on their assignments. In addition to learning about instructional uses of the computer, students are introduced to teacher utilities, programs designed for the teacher that include such titles as *Test Writing* and *Grade Book*.

Process Skill Investigations

After learning the basic and integrated science process skills, students are required to apply this knowledge by designing individual research investigations. These investigations grow out of the subject matter the students prepare for their microteaching. Worked on during the quarter and then reported to the class, these researches reinforce the process skills and give students further insights into the nature of science.

Mastery Learning

Diagnostic and prescriptive procedures play an important part in the biology courses designed for the elementary preservice student. Through multiple administrations of diagnostic tests, students can receive individual remedial assignments, and then take a different version of the exam covering the same unit objectives. This procedure is also used in testing student knowledge of elementary science content, in the same sections of the methods course. Students are allowed to retake tests for each content objective until they have attained mastery.

Hands-on Instruction

The class format of the methods course typically involves

science activities. On any given day one might see students measuring out a scale model of the solar system down a hallway or flying paper airplanes to determine what variables affect flying time and distance. Materials from ESS, SCIS, SAPA, OBIS, and many other science programs are available to students, along with a complete library center and trips to the university's marine educational facilities on the coast. The activities orientation of these classes reflects the philosophy and goals set forth in the position statements of the National Science Teachers Association and earlier guidelines from the American Association for the Advancement of Science.

Middle Grades Teacher Education

General Requirements

The Middle Grades certificate requires specialization in at least two distinct teaching fields and the completion of a state-certified four year teacher preparation program. Forty-five quarter hours (25 in the first major teaching field and 20 in the second) beyond the first two core years of college coursework must be completed in two of the following areas: language arts, science, mathematics, or social studies. In addition, all applicants for first-time middle grades certificates must take a five quarter-hour course in the identification and education of children with special needs, and must complete a five quarter-hour course in the teaching of reading.

The Professional Education Component

The heart of the professional education component of the middle grades program is four sets of courses designated as Phases I–IV. The basic courses in each phase are interspersed throughout the junior and senior years. All courses in a phase are taken as a block. Many are field based, with numerous opportunities to observe and teach in middle grades classrooms.

Phase I courses introduce the student to the nature of the middle grades and the early adolescent. College students are gently eased from observing in classrooms to working with small groups of students. Phase II courses focus on planning for instruction and the instructional process itself. Students plan and teach their own week-long units. During Phase III the focus continues to be on planning and instruction, with the students preparing and teaching a two-week unit. This phase also emphasizes the middle grades curriculum.

Phase IV, student teaching, begins with a formative component in which supervisors from the two areas of specialization, the university supervisor, and the sponsor teacher gradually give the student increasing teaching responsibility, providing feedback and suggestions throughout. During the last three weeks, while the student teacher has full-time responsibility for teaching, a summative assessment (using a state-wide assessment measure called the Teacher Performance Assessment Instrument) is scheduled and conducted by the sponsor teacher and the university supervisor (see Capie, Johnson, Anderson, Ellett, & Okey, 1979). Science education faculty supervise middle grades science teachers.

Since the state of Georgia does not certify middle grades teachers for specific subject areas, prospective teachers must be ready to teach all subjects. Therefore, all of our students take five-hour methods courses in their two non-specialty areas as well. For example, all students who identify themselves as math/language arts majors must take methods courses in social science and science in addition to their specialty methods courses.

Middle Grades Science Specialization

Each specialty area (science, math, language arts, and social studies) is responsible for advising its students for 30 quarter hours of work, whether that area is considered the first or second major concentration. In science, students usually take 20 quarter hours of science courses (in addition to the 10 quarter hours taken in the core, normally a biology sequence) and two five-hour science methods classes. One goal of science specialization is to confer as broad a science background as possible on prospective teachers so that they will feel comfortable teaching all the science topics in the middle grades curriculum. Students are urged to take science courses that match the local curricula. Since the most common local pattern is general science in sixth grade, life science in seventh, and Earth science in eighth, most students take at least five hours each of biology, geology, and physical science.

The two specialist science methods courses are field based and taught concurrently as one ten-hour course. These courses are usually taken after Phase III but before Phase IV. In general, students meet their instructor on campus for three or four two-hour periods per week, and spend the other two to four class hours in a middle grades science classroom as arranged by the instructor.

Goals for Middle Grades Science Teacher Education

The training for middle grades teachers who identify science as one of their two specialty areas has been designed to meet a set of goals adopted by the program faculty. These goals, their rationale, and a brief description of goal-related activities follow.

Goal I—Middle grades teachers should demonstrate a proficiency in the basic and integrated process skills.

The general trend in middle grades science curricula is to stress process skill objectives and activities. Science content courses generally do not allow students to become familiar with and competent in the process skills. Therefore, this need must be met in the teacher education program.

Process skill learning revolves around 16 self-instructional modules, each focused on a single process skill (Funk, Okey, Fiel, Janus, & Sprague, 1979). Each module includes a list of performance objectives, activities, self-checks, a mastery test, and ideas that can be used in the classroom. The activities require simple to use and easy to acquire materials such as candles, baby food jars, spring scales, batteries, and bulbs. Many are appropriate for future use with middle grades students.

Although the modules are self-instructional and self-paced, the students are closely monitored as they complete the activities. Class discussions and short introductory or evaluative process skill exercises are regular parts of class meetings.

Goal II—Middle grades teachers should demonstrate a full repertoire of teaching strategies and behaviors.

No single teaching behavior or strategy is effective for all situations. This is especially true at the middle grades level where the interests, needs, and abilities of pupils vary temendously. Therefore, middle grades teachers must acquire a full range of teaching behaviors and be able to use them appropriately.

Four types of activities are used to influence the teaching behavior of middle grades teachers. First, the students become familiar with two teaching strategy analysis systems, the Teaching Strategy Observation Differential, or TSOD (Anderson, Strothers, & James, 1974), and the Data Processing Observation Guide, or DPOG (Yeany & Capie, 1979). Second, they view videotaped models of middle school teaching situations and code the behaviors they observe using the TSOD or DPOG. From these tapes, they abstract and discuss general principles for teaching specific types of lessons, including lecture, demonstration, activity, and process skill activity.

Third, the students engage in peer teaching; they are videotaped and then required to analyze and code their own teaching behaviors. Research on these procedures indicates that the teachers acquire a broader set of more indirect behaviors as a result of this self-assessment. Finally, students teach several public school lessons. At least one is videotaped and critiqued by a university instructor.

Goal III—Middle grades teachers should understand and be able to respond to the needs of adolescents in terms of their social, emotional, physical, and cognitive development.

The middle grades learner is unique and perplexing, undergoing rapid change in social, emotional, physical and cognitive development. These changes cannot be ignored, since they strongly affect the learning process. Middle grades science teachers must be able to respond to the changing individual both in a personal way and through the curriculum experiences they present.

Early preservice activities designed to meet this goal center around the observation of pupils in the public schools. Students have observed middle grades pupils throughout the program, but the emphasis is now directed to science classes, where they continue to work with entire classes and individuals, including problem students. Social, emotional, physical, and especially cognitive development have been taught before, but students review them now with special attention to their effect on science learning and instruction. Two major goals are stressed: matching the learning method to developmental characteristics, and using process skill activities to promote cognitive growth.

Goal IV—Middle grades teachers should demonstrate knowledge of the range of science curriculum materials and activities appropriate for different pupils and grade levels.

Time, effort, and money have been liberally expended in recent years to develop science curricula at both local and national levels. Some of these materials are effectively designed to meet the special needs of the middle grades learner. Middle grades teachers need to be made aware of the nature and extent of these materials in order to intelligently select and/or develop the best science curricula for their own situations.

The major emphasis in this area is on examining and comparing middle grades curriculum materials, such as *Intermediate Science Curriculum Study* and *BSCS Human Sciences*, and getting to know the activity units that can be used to supplement traditional textbook programs (e.g., *Examining Your Environment* and *Elementary Science Study*). The students are also directed toward journals as sources of activities and teaching ideas (i.e., *Science and Children*, *The Science Teacher* and *The Georgia Science Teacher*). Representative activities are selected and presented to peers, who participate much as middle grades pupils would. Preservice teachers also review representative science software on topics taught in the middle grades.

Goal V—Middle grades teachers should demonstrate an ability to manage both materials and pupils in a way which maximizes learning.

One of the skills most often cited as lacking in middle grades teachers is the ability to manage time and materials while controlling pupil behavior. Order is a prerequisite to effective instruction, especially when student activity has a high instructional priority. Our program spares no effort in helping teachers to acquire the management skills they need to keep order in their classes.

During their school observations, university students record the on-task behavior of middle school students and look for teacher behaviors that correlate with either high on-task or high off-task pupil behaviors. University classroom discussions of effective and ineffective management are based on these data. We especially emphasize appropriate methods of handing out, retrieving, and storing science equipment and appropriate methods of managing students during activity lessons.

In one successful role-playing activity, a student engages in peer teaching while peers act out roles related to typical behavior problems. The peer students are instructed on how to project this misbehavior during instruction. The "teachers" are judged and counseled on their ability to identify and control the behavior problems.

Goal VI—Middle grades teachers should plan and prepare science instruction for achieving objectives with learners of different abilities and interests.

Careful planning and preparation is the first step toward success in any venture. Planning for middle grades teaching requires not only knowledge of content and organizational skills, but also an attitude that values planning. The function of the training program, then, must be to instill both skills and attitudes in the middle grades teacher.

The planning emphasis here is a continuation of training that starts very early in the middle grades program, so students have already mastered most of the basic skills in planning. The task now is to direct these skills toward objective writing, lesson planning, and unit planning for science instruction.

Students practice writing behaviorally stated objectives, using Bloom's taxonomy, and selecting and writing science-specific objectives. They review lesson planning and write several plans during the course, for microteaching and middle grades teaching sessions and for their final unit plan. Since unit planning brings the teacher's creative abilities to bear on the many resources already available, unit

development is a natural outgrowth of the review of various curriculum resources. Students submit a unit as one component of their summative evaluation. They receive formative feedback regarding this unit at various times throughout the course.

Goal VII—Middle grades teachers should be able to construct formative and summative measures of science objectives.

An important but often neglected area of teaching is assessment and evaluation of instruction and pupils. Only through objective assessment of desired outcomes can the planning and execution of lessons be judged for effectiveness. Also, it is only through systematic assessment of pupil achievement that we can diagnose learning difficulties and make decisions about the learner's acquisition of skills and concepts. We make every effort to impart sound measurement techniques to our middle grades teachers.

The characteristics of a good classroom test and the reasons for testing are reviewed and discussed in regard to science instruction. Instructors stress the importance of using a table of specifications to be sure those characteristics are present. The class discusses different types of tests, underscoring the concepts of formative and summative evaluation and the uses of pretests.

Item construction is strongly emphasized and practiced, with the proper use of multiple response, short answer, and essay items examined and discussed in a science context. Discussion also covers the construction and implementation of a laboratory practical exam suitable for middle grades students. Students then construct both formative and summative measures for a unit of instruction.

Goal VIII—Middle grades teachers should be able to identify resources available through professional organizations and journals.

Any well-rounded professional is aware of the organizations and publications unique to the profession and understands the purposes and services of each. Many publications and several organizations can serve as excellent resources for middle grades teachers. Our training activities call attention to these sources of ideas, information, and assistance.

The activities related to this goal are interspersed with other goal-related activities. For example, students examine the how-to and curriculum review sections of journals when they are assessing curriculum materials. The special middle grades services and materials of the National Science Teachers Association are explored in this process.

Goal IX—Middle grades teachers should be able to use the computer to enhance science instruction.

Each middle grades teacher is given four to six days of basic computer instruction, which includes using the computer for testing and grading, and evaluating science software. In addition, about a third of our middle grades students take a special five quarter-hour course, Microcomputers and Science Education. This course emphasizes general computer literacy, word processing, simple programming techniques, and software review, as well as the use of teacher utility programs. The course is taught by science education department faculty.

Methods for the Non-Science Major

The science methods course for those students not selecting science as a major field has objectives similar to those of the major's course. However, by necessity, the treatment of these objectives is somewhat abbreviated. Other differences are that the course is not field based, students do less microteaching, and there are fewer total hours of coursework (50, versus 100 for majors). Since most of these students have a poor attitude toward science, the course gives special emphasis to relieving their anxieties and fears and replacing them with positive attitudes.

Early and Middle Grades Programs: What Needs To Be Done?

The department of science education faculty would like to see additional science courses made a prerequisite for early childhood science teachers. Although a special physics class for elementary teachers was offered, there has not been enough enrollment to support it. Students avoid chemistry and physics by taking their required science courses in biology and geology. We need to add another course requirement in the physical sciences.

Another major problem area is the lack of subject matter certification at the middle grades level in the state of Georgia. Presently the state has a surplus of teachers in language arts and social studies and a shortage in science and mathematics. Because there is no subject matter certification, an administrator can legally place any middle grades certified teacher in a science classroom. Those without science as a specialty have only minimal preparation to teach science, usually two content courses and one methods course. Many do an inadequate job. While professional educators have long argued for subject matter certification, it seems unlikely that this will come about soon. Many small, rural school districts would be especially hard hit by a change, due to the lack of teachers in math and science and their inability to attract those who are available.

The evidence collected from supervisors of student teachers and principals indicates that our program prepares excellent middle grades science teachers. Above all, the program prepares individuals who want to be middle grades teachers and who want to work with preadolescents and young teens. This is a distinct, positive, and much needed change from the situation of recent years.

Program Maintenance

The most important factor in program maintenance for the department of science education is continuous program review. Every two to three years department faculty thoroughly review all programs in the department. Changes usually reflect changes in the public schools and other early childhood and middle grades programs, as well as new curricula and teacher training techniques.

Evaluation

Formative and summative evaluations are conducted to see if students are attaining the objectives of the program. Both the student and the program are evaluated. In the early childhood methods course students are given pretests measuring their content and process knowledge. The content test is derived from the released items of the National Assessment of Educational Progress (NAEP), and is updated

with newer items as NAEP releases them. The NAEP items were intended to assess the science literacy of nine, 13, and 17 year olds. The released items for the nine and 13 year olds are given to the early childhood preservice teachers as a pre- and posttest to evaluate the program's effectiveness in improving their science content knowledge. These scores are not criterion referenced to course objectives and are not included in the student's grade. Criterion referenced content items are administered at the end of the quarter and in some classes in a mastery learning model. In this model, students can continue taking some form of the test until they master the objectives.

Process skills in both the early childhood and middle grades programs are evaluated using two instruments developed in the department. The basic process skills are measured by using the Basic Process Skills Test, or BAPS (Padilla, Cronin, & Twiest, 1985). The integrated process skills are measured using the Test of Integrated Process Skills (TIPS: Okey & Dillashaw, 1979).

We will build on our own strengths, and learn from those of our peers, as we continually improve preservice elementary education at the University of Georgia.

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Chapter 5
A Comprehensive Training Program for Preservice Science Educators

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Eastern Michigan University (EMU) is a multipurpose institution whose roots date back to 1849, when it was established by the Michigan Legislature to educate teachers for the state's public schools. During its first hundred years the Michigan State Normal School, as EMU was then called, certified thousands of teachers. It continues to emphasize teacher education today, even though it has broadened its scope and diversified its programs since becoming a university in 1959. Eastern Michigan is one of the largest teacher education institutions in the nation and is widely respected in this field.

Student enrollment has continued to increase during the 1980s, in spite of rising tuition and a falling college-age population nationwide, reaching 20,200 during the winter 1985 term. EMU's focal point is southeastern Michigan, an area of small cities and towns like our home base, Ypsilanti, population 24,000. Thirty miles to the east is Detroit, industrial and business hub of the Great Lakes; an equal distance to the south is Toledo, northernmost city on the Ohio border.

In the fall of 1968 representatives from four science departments—biology, chemistry, geography and geology, and physics and astronomy—formed a committee to study ways to improve the science education program for elementary education majors at Eastern Michigan University. Prior to that time, elementary education majors were allowed to elect a four-credit-hour introductory course in each of two science fields and a three-credit-hour course in methods of teaching elementary science. Most elementary education majors elected to take courses in biology and Earth science. Because they were intimidated by the more quantitative sciences, most of them received no preparation in either chemistry or physics.

The committee studying this problem met weekly for several semesters, and after many hours of discussion, formulated objectives for an elementary science education program and plans for a pilot project to achieve these objectives. They agreed to set up a new science program for training elementary teachers as an alternative to the regular university program. This optional program, would require its students to take four separate three-semester-hour courses in physics, chemistry, Earth science, and biology. The program would be spread over four semesters, ending no later than the middle of the student's senior year. The course in methods of teaching science could be omitted because teaching methods would be included in each of the four discipline courses.

For five years the four courses were taught as a pilot project with volunteer student participants. In 1975 the university recognized the project for the strengths that it added to the elementary education major by making it a requirement for all students in that field. Nearly every student who has enrolled in the early and later elementary curriculum since the adoption of the program has graduated from the university with at least one course in each of the four sciences: biology, chemistry, Earth science, and physics. These same courses provide specialized instruction in the techniques of teaching each science subject to elementary school children.

Our Program

In order to provide prospective elementary science teachers with a comprehensive background in science content and teaching methodology, the College of Arts and Sciences and the College of Education at Eastern Michigan University have developed a program that is innovative in at least six respects.

- Teacher-trainees complete courses in each of the four major areas of science—biology, chemistry, Earth science, and physics.
- Four separate science departments and the teacher education department have joined in the program's planning and continued review and revision.
- The program blends methods and content into an integrated teacher education curriculum. Methodology instruction is incorporated into each of the four courses. As a result, the trainee learns how to teach science at the same time that he or she studies content material.
- The concepts taught in the courses are selected to match the basic scientific understandings elementary school teachers need.
- The laboratory portion of each course is designed to give the prospective teachers hands-on experience with simple and inexpensive laboratory materials. These activities introduce science principles, teach process skills, and develop scientific attitudes.
- Throughout the program, trainees teach science to children in local elementary schools. These experiences begin with small-group microlessons and gradually build to the teaching of full-period lessons to entire classes.

Blending methods and content into an integrated teacher education program, our courses stress the basic understandings elementary school teachers need. No attempt is made to cover every aspect of content as might be done in traditional college science courses. The laboratory program is designed to give prospective elementary teachers hands-on experience with simple and inexpensive laboratory materials. Furthermore, the laboratory program provides experience with all the process skills recommended by the Michigan State Department of Education.

The total program departs from standard teacher training programs in its laboratory emphasis, content, methodology, materials, and curriculum.

Laboratory

The learner is actively involved in a greatly modified science laboratory setting. In traditional laboratory programs the learner is given sophisticated materials that illustrate science principles already presented by the lecturer. In our program the laboratory experience, using simple apparatus or equipment the students have made themselves, is the catalyst for active inquiry. Out of the laboratory experience comes understanding about the science endeavor and its impact on people and society.

Content

In the traditional program the student moves through individual science courses which are presented as if they were unrelated to one another. In contrast, our elementary science program involves students in four science disciplines in a manner which reveals the intricate relationships between the physical and biological sciences. Each student actively participates in the four-course program using laboratory experiences as the medium for science content.

Methodology

The standard, isolated methods course has been eliminated in our elementary science program. Instead, methodology is included along with the content at those times when it is most appropriate. Students take part in a large number of methods activities, including lesson and unit planning, microteaching experiences, computer assisted instruction, and evaluation of various science textbooks. In addition, students often attend science conferences and judge at science fairs. Integrating methodology with content has proved far superior to the former approach.

Resources and Curriculum

Science for Elementary Teachers—Earth Science

Earth science instruction belongs in the elementary school. It is especially effective when it is integrated with physical science and biological science in the curriculum. Experience has shown, however, that elementary school teachers generally shy away from teaching Earth science topics unless they have considerable background in the subject. Our Earth science course ensures that EMU-trained elementary teachers have received adequate and up-to-date instruction, both in subject matter and methods of teaching Earth science.

The lectures given in the course describe and demonstrate non-quantitatively some of the basic Earth science principles dealing with the materials of the Earth, processes at the Earth's surface and within its atmosphere, and Earth history. Recitation/lecture sections permit the students to interact with one another and their instructor regarding the elementary school level. The instructor makes every effort to stimulate interest in Earth science and to convey its interdisciplinary nature. No one can fully understand any of the Earth science processes without at least a beginning understanding of physics, chemistry, and biology.

The laboratory portion of the course is designed to lead the student to discover some of the basic Earth science concepts. The investigations deal with minerals, rocks, soil, streams, fossils, geologic history, weather, and topographic maps, using simple, inexpensive equipment of the type that is readily available for use in the elementary school classroom. The laboratory experiences are similar to those which the teacher will in turn present at the elementary school level.

Science for Elementary Teachers—Biology

The goal of the course is to prepare students to teach the biological aspects of modern elementary school science. The lecture portion of the biology course introduces biological principles that are basic to most college biology courses and emphasizes those that are found in elementary science programs. They include characteristics of living things, plants, animals, ecology, systems of the human body, and environmental education. Students explore these content areas through laboratory and field work experiences using simple equipment and materials.

The laboratory investigations stress exploration and discovery and are selected for their appropriateness to ele-

mentary teaching. Students are given the opportunity to try some of these investigations with children as they teach science lessons in local elementary schools. During the course, the teacher-trainees teach at least four science lessons in early and late elementary classrooms. In planning their lessons they make extensive use of the science teacher education center, located next to the biology education classroom and housing elementary science curricula from more than 20 publishers.

Other laboratory sessions provide opportunities for the students to explore such topics as using the school site to teach science, organizing the classroom for science teaching, and the use of computers in science teaching. A major goal of the course is to allow students to experience the fascination of science and to gain confidence in their ability to teach it.

Science for Elementary Teachers—Chemistry

The lecture portion of the chemistry course includes many of the basic topics found in introductory textbooks. Special emphasis is given to topics suggested in the American Association for the Advancement of Science Guidelines for Preservice Science Education of Elementary School Teachers. Topics that receive heavy emphasis because of their relevance to the chemistry found in many current elementary science programs include introductory atomic theory, properties of states of matter, behavior of gases, solubility and solutions, common chemical reactions, and acids and bases. The course is structured to eliminate any separation of textual material from laboratory work. In this way it resembles the approach used in the Physical Science for Nonscience Students program which was developed with support from the National Science Foundation.

Like the other three science courses in the program, the chemistry course involves considerable laboratory work. Experiments are based on activities frequently found in elementary science curricula. Whenever possible, simple equipment is constructed from readily available materials, using chemicals which can be obtained from grocery stores, drug stores, and other local sources.

Students gain practical teaching experience by conducting classroom demonstrations, presenting lessons to fellow students, and teaching microlessons with elementary students who are brought into the chemistry classroom.

Science for Elementary Teachers—Physics

The lectures given in this course describe and demonstrate in qualitative terms some of the basic physical principles dealing with matter and measurement; the effect of forces on matter and on the motion of bodies; work, energy, and heat; the nature and properties of wave motion, with applications to sound and light; the properties and effects of electricity and magnetism; and the history and current state of astronomy, particularly in relation to the solar system.

Recitation sections of no more than 20 students enable the members of the class to interact with each other and the professor about the basic scientific principles and processes that pertain to elementary education. The course stimulates interest in science and insight into its processes, rather than offering a large body of knowledge to be memorized and dealt with in a mathematical and theoretical manner.

The laboratory portion of the course leads the student into a rediscovery of some of the basic principles of science. Students learn to use inexpensive equipment of the type that is found in elementary school classrooms. They practice the basic kinds of measurement used in science processes and gain confidence in their own ability to do science. The laboratory experiences are similar to those the teacher can and will direct in the elementary school, and deal with density, buoyancy, pressure in fluids, elasticity in solids, measurement of force and motion, properties of sound and light, magnetism, and the effects of electricity.

The textbook has been selected from physical science books written at an elementary level and uses a very simple mathematical approach.

Because teachers teach as they are taught, the elementary education science program provides the kinds of instruction we expect prospective teachers to give their students. This includes extensive hands-on experience with simple and inexpensive laboratory materials. Putting simple equipment into the hands of prospective teachers helps them overcome their fear of science and builds their confidence in their own ability to teach it.

In addition to the University Center of Educational Resources and the Instructional Materials Center, students in the elementary science program have access to two other resource libraries. One is located in the biology department and contains a wide collection of elementary science textbooks, periodicals, teacher resource books, equipment, and a microcomputer. The other library is located in the physics department and contains science programs and materials primarily related to middle school and junior high school. The physics department also houses a Science Materials Center where students may check out teaching materials to use during their student teaching or, after graduation, in their own classrooms.

Our students learn to use outside resources through the numerous field trips the program provides. They visit the Detroit Zoo, the Detroit Science Center, the University of Michigan Botanical Gardens, and the University of Michigan Museum of Natural History. In addition, students are given an opportunity to attend at least one science education conference each semester. University transportation is provided for those who participate. During the past year, students have attended conferences of the Michigan Science Teachers Association, the Metropolitan Detroit Science Teachers Association, and the Michigan Environmental Education Association. Students also have the opportunity to take classes at the Kresge Environmental Education Center, owned and operated by Eastern Michigan University. The Center consists of a 240-acre tract of land which includes a variety of terrain, vegetation, and animal life. Classroom, dining, and lodging facilities are available at the Center for students and staff.

Evaluation

At the time that the elementary science education program became a requirement for elementary teachers, an extensive series of surveys was done to determine what should be included in the program and to obtain information concerning its graduates.

Feedback obtained through questionnaires, student eva-

luation reports, and unsolicited comments from students enrolled in the project has been very favorable. Students report that the program gives them the type of preparation they need to teach science to children, and that they much prefer the type of instruction they have received to that provided in the regular introductory science courses.

The University Council on Teacher Education is the major intercollege agency responsible for monitoring the teacher education programs. The four science departments recently made an extensive presentation to the council regarding the science education component. The council was in agreement that the programs lend strength and continuity to the teacher training curriculum, and extended its continued support.

Every instructor of the required science courses is evaluated each fall by the campus-wide student evaluation program. While the questions are mainly directed to the quality of instruction, students also express opinions about the nature of the courses. Their responses are invariably very supportive of the program.

In addition to these formal evaluations, much evaluation has been done by informal means such as talking to students and graduates. Instructors of the science courses spend extensive time in area schools observing the performance of students currently enrolled in the program and its graduates.

Numerous students come back to their science instructors after completing the course to borrow science equipment and materials to use in their student teaching. Supervisory teachers and employers report that the graduates do teach science and teach it well.

Response to Evaluations

The four science courses have been changed over the years since they were first instituted because of the formal and informal feedback just described. Some of the more significant changes that have been made are:

- Increased practice with actual science teaching, both to peers and to elementary students
- Wiser selection of content: courses have become more practical and less theoretical
- Greater emphasis on the methods and professional aspects of teaching science
- More appropriate experiments, as course activities have been revised by instructors over the years
- Greater exposure to a wider variety of activities, including examination of and use of commercial elementary science programs
- Increased numbers of students and faculty attending and participating in science conferences
- Increased numbers of faculty and students serving as judges at science fairs, and an increase in the number of fairs judged

Plans for Improvement

We would like to have the students enrolled in the four science courses participate in a greater number of TV microteaching experiences. Since one of our instructors served as director of the microteaching laboratory at Weber State College, he is qualified to instruct and supervise students in the use of this technique. In conjunction with the other training techniques, additional TV microteaching should be a useful adjunct to our program.

We are currently in the process of writing a proposal to the National Science Foundation to fund several portable TV cameras and playback equipment. If we obtain this basic apparatus, our students will have additional opportunities to teach brief lessons to small groups of elementary school pupils while being videotaped.

Then, in addition to the usual methods of evaluating the lesson (pupil feedback, supervisors' critiques, etc.), the teacher trainee will have chances for continuous self-evaluation, because the lessons will be on videotape. There will be a permanent record against which to measure future performances. If the student has failed to demonstrate mastery of, for example, asking questions effectively, he or she can teach the same lesson later to another group of students. The trainee can master each skill in turn before moving on to the next.

Another aspect of our program is its emphasis on computer-assisted instruction. In the near future, Eastern Michigan University students enrolled in the early and later elementary curriculum will be required to take a one-credit-hour microcomputer course. We expect that these students will come to the science for elementary teachers courses with a basic foundation in the educational applications of computers.

We plan to build on this background and continue to provide opportunities for them to examine and evaluate the science software used in elementary school teaching. More importantly, they will explore those data base management and spread sheet systems which are appropriate for elementary school pupils. These systems provide an exciting new tool for elementary pupils to synthesize information and draw generalizations from it.

Chapter 6
SODIA Science

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The acronym SODIA sums up the Utah State University elementary teacher education program. The name is derived from the first letters of five descriptive words—Self, Others, Disciplines, Implementation, and Associate Teaching—which represent the five levels of the program.

Level I, Self, is represented by the letter S in the acronym. At this introductory level we develop the student's understanding of the relationships between personal characteristics and the ability and desire to teach. Students in Level I spend a minimum of 10 hours observing in elementary schools at various grade levels. Classwork and counseling provide a variety of other experiences to help students decide whether teaching is really the profession they want to pursue.

Level II, Others, is represented by the O in the acronym. Entrance to Level II requires prior admission to teacher education, awarded after successful completion of Level I, and a 2.5 grade average. In this block students are assigned to one of the cooperating public schools, where they spend approximately half of each day working in classrooms as tutors and aides. They spend the rest of their time in seminars and classes, either at the portal schools or on campus. The 15 hours of courses include Educational Psychology, Education of the Exceptional Child, and Foundation Studies in Teaching, as well as the Practicum in Elementary Education.

Level III, Disciplines, is represented by the D in the acronym. Students are assigned to classroom and seminar experiences at the Edith Bowen Laboratory School on the USU campus, where they take 18 hours of methods courses in reading, social studies, language arts, science, and mathematics. They diagnose, prescribe, teach, evaluate, and reteach in all five subject matter areas. Students develop a variety of methods and approaches using diagnostic and prescriptive techniques.

Level IV, Implementation, is represented by the I in SODIA. This is the student teaching phase of the program. Students spend a full quarter teaching in the schools in their junior year.

Level V, Associate Teaching, is the A in the acronym. Associate teaching is an optional, individualized program for senior students who have successfully completed their student teaching and want additional experience in the schools. Students may earn from three to 12 extra credits, functioning as full-fledged members of the teaching team under the direct supervision of the cooperating teacher. Associateships are for the full academic year. Associates work with a master teacher and receive 5/8 salary.

In the program's early years both students and faculty consistently reported that the Level III methods term placed excessive demands on students. Over the years successive adjustments were made to achieve a reasonable balance between methods course requirements and practicum experiences. The number of college class hours in the 15 credit hours of methods courses was reduced, on the grounds that students learned theory as well as practice in their elementary classroom experience. While this may have been true for the other content areas, many students reported that their classroom assignments offered little or no opportunity to teach science.

For this reason, the on-campus time for the science

methods course was increased to more nearly match that of a standard three-hour content course. Even after this adjustment, however, students consistently indicated that they wanted more time for science methods, and gave high ratings to the science methods course.

At about the same time, national and state concern for the science competencies of elementary teachers (National Science Board, 1983; Milne, 1983; Daugs, 1983) led to meetings between College of Science and College of Education faculty. A USU Science Education Advisory Group was initiated in 1983 to include the dean of education, the dean of science, two science educators, and the biology, geology, physics, and chemistry department heads.

As a result of the group's recommendation, USU changed the science requirements for elementary school teachers and developed a new science methods course. The changes met or exceeded the 1983 NSTA recommendations for certification of elementary teachers.

The science methods course, including a science-only practicum, was made a five-credit prerequisite to the Level III course block, and introduced as an intermediate step between Level II and Level III. This requirement insured a more uniform exposure to science teaching than had been possible in the previous program.

Rationale

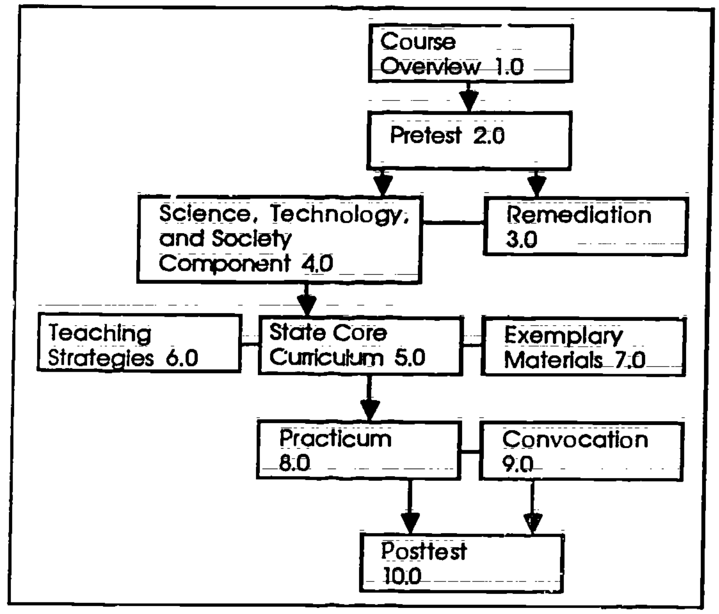
Early research (Rutledge, 1957; Beryyessa, 1959; Wishart, 1961) revealed a positive correlation between science background and various science and nonscience teaching competencies. More recent research (DeRose, 1979; Fitch, 1979; Donellan, 1982) demonstrates that many elementary teachers feel unqualified to teach science because of their poor preservice preparation.

Although there is almost universal agreement on these findings and on the importance of science education, few colleges and universities have matched research findings with program offerings. Many science educators have emphasized the importance of the content foundation in process-oriented science (Blosser, 1969; Victor, 1974; McDermott, 1976; Suchman, 1976; Rowe, 1978). Yet only one-third of the institutions Stedman surveyed in 1982 had designed their science content courses to meet the needs of elementary teachers.

AAAS guidelines released in 1970 called for a match between science topics that are taught to children and those that are taught to teachers. In accordance with these guidelines and the weight of research evidence, our advisory group recommended changes in the content offerings for Utah State elementary education majors. Science content courses were revised to cover all the components of the state-mandated Utah Elementary Science Core. The new required courses are Biology 101, Chemistry 101, Geology 101, and Physics 120, each offering five credits.

The methods course is organized around ten components, as illustrated in the figure, a composite flowchart.

Curriculum goals and objectives for each component are presented in the section that follows in the form of a conceptual framework. The framework lists the major goals and objectives upon which the content and activities of the new course are based, and also serves as the basis for first level evaluation of student competency.



Program Goal 1.0: To provide an overview and outline of course requirements and procedures

Topic 1.1 Course Outline

The student should be familiar with the components of the course.

Topic 1.2 Requirements and Grading

The student should

- Be aware of course requirements and options for achieving them
- Understand grading procedures for all components of the course

Topic 1.3 Record Keeping

The student should be able to use computer-managed record keeping procedures to demonstrate progression within the course.

Program Goal 2.0: To determine student level of scientific literacy

Topic 2.1 Content Area Assessment

The student must achieve a score of at least 80 percent in each of the four content area assessments—biology, geology, chemistry, and physics.

Topic 2.2 Science Process Skills Assessment

The student must achieve a score of at least 80 percent on a comprehensive science process skills assessment.

Topic 2.3 Science Attitude Assessment

The student must attain a score of at least 80 percent on a science attitude assessment.

Program Goal 3.0: To facilitate remediation of deficiencies identified in pretest procedures

Topic 3.1 Science Content Deficiencies

The student who is below criterion in any of the four major science content areas (2.1) must do one of the following:

- Enroll in or audit courses in that area
- Use a computer-mediated instructional program in that area
- Arrange an individual remedial program with a faculty member

- Propose, and have approved by the course instructor, a student-designed remedial program

Topic 3.2 Science Process Skills Deficiencies

The student who is below criterion in science process skills (2.2) must do one of the following:

- Use instructor-specified exercises from prescribed sources
- Attend and participate in scheduled science process skills improvement sections

Topic 3.3 Science Attitude Deficiencies

The student who is below criterion in science attitude (2.3) must do one of the following:

- Review with the instructor any attitudes specified in the pretest that contributed to a low score
- Discuss, on a one-to-one basis with the instructor, possible implications of science attitude for future science teaching
- Devise a personalized improvement plan and set goals to improve attitude toward science
- Participate in science/math anxiety alleviation exercises

Program Goal 4.0: To provide a fundamental understanding of science and technology, in order to make informed decisions about the interactions of science, technology, and society

Topic 4.1 Science and Technology

The student should

- Compare and contrast science and technology
- Appreciate how science and technology contribute to new knowledge

Topic 4.2 Impacts on Society

The student should

- Examine past and present examples of the impact science and technology have had on society, economic growth, and the political process
- Infer global perspectives on the interrelationships among science, technology, and society

Topic 4.3 Practical Applications

The student should

- Examine issues that affect her/his life, family, and community, and that relate to themes of broader significance
- Focus on one or more contemporary problems that can be examined in a scientific manner
- Use decision-making strategies to answer the question: "What can I really do?"
- Conduct a personal investigation in the area of science, technology, and society

Program Goal 5.0: To provide background on the origin and requirements of the Utah Elementary Science Core (UESC)

Topic 5.1 Elementary Science Core Overview

The student should

- Be familiar with the UESC numbering system in order to use it in a computer-assisted curriculum
- Be familiar with the hierarchical arrangement of standards and objectives stated in the UESC
- Examine across-the-curriculum relationships as presented in the Resource Guide to the UESC
- Understand and explain how all aspects of the Resource Guide relate to the UESC

Program Goal 6.0: To apply teaching principles, skills, and methods to teaching elementary science

Topic 6.1 Scientific Literacy

The student should

- Be able to define scientific literacy
- Identify and/or devise lesson plans that promote scientific literacy
- Identify and/or devise means of assessing student levels of scientific literacy

Topic 6.2 Cognitive Processes

The student should know and apply principles of cognitive psychology to teaching elementary science.

Topic 6.3 Interdisciplinary Aspects

The student should

- Be able to relate science objectives to goals and objectives in other subject matter areas at the same grade level
- Be able to identify and/or plan science lessons that integrate other subject matter areas with science

Topic 6.4 Laboratory Techniques and Equipment

The student should

- Be familiar with laboratory equipment commonly used in elementary science programs
- Be aware of hazards and safety precautions associated with elementary science laboratory work

Program Goal 7.0: To familiarize students with exemplary elementary science curricula

Topic 7.1 Curricula Produced by Industry and Non-profit Organizations

The student should be able to describe the major features of *Project Learning Tree*, *Project Wild*, *Water Education K-6*, and *Energy and Man's Environment* materials.

Topic 7.2 Curricula Produced by Commercial Publishers

The student should

- Be able to describe the major features of one or more commercial elementary science textbook series
- Be able to describe the major features of one or more commercial elementary science process-based curricula

Topic 7.3 Journals and Supplementary Materials

The student should

- Be familiar with *Science and Children*, *Science Scope*, and similar publications
- Be familiar with a variety of commercially-produced teaching aids

Program Goal 8.0: To provide the opportunity for students to teach a series of science lessons in an elementary or middle school classroom

Topic 8.1 Practicum

The student should

- Contact a cooperating teacher and make plans to teach three or more science lessons
- Submit appropriate lesson plans to the cooperating teacher for approval prior to teaching
- Teach three or more science lessons in an elementary or middle school classroom
- Submit lesson plans, a self-evaluation, and the cooperating teacher's evaluation for the instructor's final review

Program Goal 9.0 (optional): To provide a culminating experience that demonstrates science and teaching competencies

Topic 9.1 Excursion or Convocation

The student may either

- Plan and make all arrangements for a special science learning experience for a small group of children, or
- Conduct a science convocation

Program Goal 10.0 To provide a means of measuring growth and exit level of performance

Topic 10.1 Posttest

The student should demonstrate mastery of all course objectives at prescribed criterion levels.

Conformity to NSTA Recommended Standards for the Preparation and Certification of Science Teachers, 1983

The rationale for the SODIA science methods course is similar to the rationale for the NSTA standards. The first NSTA standard reads as follows:

> All colleges and universities should require a minimum of 12 semester hours or 18 quarter hours of laboratory or field-oriented science, including courses in each of these areas: biological science, physical science, and Earth science.

The SODIA science program exceeds this standard in that all students are required to earn a total of 20 credits, five each in biology, geology, chemistry, and physics. Each of these courses has a laboratory component.

Our program also follows the 1970 AAAS guidelines which recommended that preservice courses relate to the science taught in the schools. The four SODIA content courses cover all the objectives of the Utah Elementary Science Core.

Our new methods course meets the second NSTA standard in all respects. This standard concerns science teaching methods. It reads as follows:

> Preservice elementary teachers should be required to complete a minimum of one separate course of approximately three semester hours in elementary science methods. This course should be scheduled after the science content courses and just prior to student teaching.
>
> Standard II b adds that this course should help preservice teachers teach science processes, attitudes, and content to children in grades K–6.
>
> Our methods course emphasizes the content, process, and attitude components of scientific literacy. Process skills are learned through hands-on activities, and content is directly coordinated with curricula appropriate for elementary grade children. The following course components relate specifically to this recommendation:

- Topics 2.1, 2.2, and 2.3 Content, process, and attitude assessment
- Topic 6.1 Scientific literacy
- Topic 6.2 Cognitive processes
- Topics 7.1, 7.2 Curriculum materials

The third area of emphasis in the NSTA standards is field experiences with children.

> Preservice elementary teachers should have opportunities throughout their undergraduate years to teach science to children in schools. These field experiences in science should begin with observation and tutoring and proceed through small and large group instruction. Student teaching must include experiences in planning and teaching science.

The initial experience with students in Level II of the SODIA program may or may not include science lessons. The classroom exposure at that level is unstructured to the extent that students may or may not be present at a time when science is being taught. The practicum component of the science methods course, however, provides every student the opportunity to teach science. This is followed by Level III, a full quarter practicum during which every student is required to teach science. The culmination is a quarter of full-time student teaching that normally includes science lessons.

Standard four deals with faculty preparation. Faculty for both the content and the methods course in the SODIA program meet NSTA recommendations. Methods course faculty are well versed in content and in teaching methodology. The principal instructor is a senior faculty member with a Ph.D. in science education.

Standard five emphasizes the value of an atmosphere in which students can explore, investigate, and discover. Preservice teachers should experience scientific inquiry because teachers prepared in environments that invite and support curiosity, investigation, and inquiry are likely to provide similar situations for their students.

> Preservice elementary teachers should be instructed in science laboratories and educational facilities with equipment, instructional materials, and library holdings that promote science learning and exemplify outstanding school science programs.

Our combination of science course laboratories; our science, technology, and society methods course component; and our Edith Bowen Lab School facilities collectively satisfy the requirements of this recommendation. Our one area of deficiency is that we have no annual budget for supplies and equipment.

The final NSTA standard defines conditions relative to professional development. These criteria range from positive attitudes toward science to an appreciation for the position of science in the total elementary curriculum.

> The professional orientation of preservice elementary teachers should include experiences that (a) instill positive attitudes toward science and science teaching, (b) foster an appreciation for the value of science in the total curriculum and in the lives of children, and (c) develop a commitment to continue their education as teachers of science through reading, participation in professional organizations, and further education, including inservice experiences.

Item c above has not been evaluated, but items a and b are integral parts of the philosophy and objectives of our methods course. We expect to continue to develop toward the vision of excellence embodied in the NSTA Standards and the SESE Criteria for Excellence in Preservice Elementary Education.

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Chapter 7 Collaboration in Preservice and Inservice Education: A Needs-oriented Model

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Our needs-oriented model involves three groups—preservice teachers from Austin Peay State University's Education Department, inservice teachers from Barksdale Elementary School, and Barksdale elementary students (K–5). Both the university and the elementary school are in Clarksville, Tennessee, a community of 85,000 near the Tennessee/Kentucky border which is home to a military institution (Fort Campbell) as well as the state university.

Of Austin Peay's 5,000 students, approximately 15-20 percent are elementary education majors, most from seven counties across the state and some from outside the state. The traditional agrarian nature of the community and its close proximity to Tennessee Valley Authority Land Between the Lakes, Mammoth Cave State Park, Dunbar Cave Natural Area, Montgomery Bell State Park, and Reelfoot Lake provide many opportunities for hobbies and interests related to science and the outdoors. Clarksville's industrial resources include Acme Boot, Trane, Thun, Jostens, and Union Carbide.

Determining the Need

"The only person who knows what I need to learn is me." That's why our model was designed to respond to the expressed needs of the three role groups whose needs concerned us most as educators: preservice teachers, inservice teachers, and elementary students.

In 1980 we administered a questionnaire to three Montgomery County elementary faculties. Inservice teachers identified very similar reasons for either not teaching science or not feeling competent as science teachers. At approximately the same time, 90 preservice teachers in preparatory classes at the university were asked to identify competencies they wished to gain from their science education course. The outcome of these two assessments was a collaborative model integrating preservice and inservice education through science labs or centers established in the elementary school.

The Needs Inservice Teachers Express

The inservice teachers named eight elements which hampered their teaching of science.

- The various reading levels and ability levels of students
- The lack of appropriate, up-to-date reading materials, as well as laboratory materials, equipment, and funds
- The lack of time for preparation of materials
- The lack of appropriate space for work and storage
- Problems with labs: extra noise, movement, and cleanup; behavior problems
- Lack of motivation and poor attitudes toward science on the part of students
- Inadequate scope and sequence of the science program; inadequate measurement and evaluation of student progress
- Personal discomfort and lack of confidence

Barnes' 1981 research describes the inservice training he saw as generally remedial in nature. He found that such training usually stems from untested assumptions of what teachers need, and has general, rather than specific application to problems and shortcomings. Inservice is offered as a sort of universal remedy, for problems which are always individual and specific.

The Competencies Preservice Teachers Want

During that same period we asked Austin Peay preservice teachers to identify the competencies they hoped to gain. Their answers centered around skills in eight areas:

- Designing science units, writing lesson plans, and choosing and using educational materials, including evaluation materials.
- Developing self-awareness and self-confidence, including class management and discipline skills
- Strengthening the child's self-concept, fostering positive science attitudes, and reducing science anxiety for students
- Meeting the individual needs of students through strategies such as individualized instruction and the use of learning centers
- Communicating with and learning from other teachers
- Becoming familiar with the resources of the school and the school system (facilities, environment, and organization)
- Gaining perspective on career decisions such as grade level preference

The Opportunity Students Deserve

What students need from their elementary science programs has been exhaustively documented in recent years, along with the fact that few of them are currently having those needs met. Teachers do not devote adequate time to science instruction. A great deal of the instruction that does occur is still a matter of isolated facts and principles. Too many students regard science content as boring, and science labs as "yucchy." Classes are large, and teachers have little time to recognize or respond to individual interests and learning styles.

Educators cannot expect to put the pieces together, to capitalize on curiosity and mold problem-solving and inventive minds, unless their teaching builds integrated conceptual models. They can only do this by allowing children to apply learning, to initiate investigations, and to solve real or realistically simulated problems. Teachers must be prepared to teach process skills, as well as science content, in a logical, progressive, meaningful sequence to meet the needs of today's students and prepare tomorrow's scientifically literate adults.

The Science Center Model: A Rationale

What followed seemed only logical—to develop a training model to integrate the education of preservice and inservice teachers and enrich, supplement, and even restructure the existing elementary science curriculum by combining forces and resources. The key to the model would be the expressed needs of inservice and preservice teachers.

Wiles lamented in 1979 that educators are accustomed to viewing preservice and inservice training as two unrelated processes, even though the competencies the two groups need appear to be the same. Nothing has changed. In addition, inservice training has remained under the auspices of local school districts, while preservice has been considered the university's domain. Many educational theoreticians consider separate programs with separate coordinating systems an unhealthy split in teacher education. They recommend a marriage of the two programs for the benefit of teacher trainees, teachers, and students (Winter, 1965).

Collaboration is the foundation for our model's success. Preservice training and service to the school are tailor-made in this program—designed by the inservice teacher, principal, teacher educator, and preservice teacher, with the needs of the students in full view, to use the resources of this particular setting for the benefit of all concerned.

Our Program

The program is built around the science center located in the elementary school. The center is a workplace and learning lab providing space for science equipment, resources, experimentation, and storage. Staffed by trained parent volunteers and preservice teachers, it operates much like an open-concept library.

It is also a place for preservice teachers to hang their hats. Equipped with test tubes, hot plates, bulbs, wires, aquariums, plants, skulls, fossil collections, insects, and rodents, the science center is an ever-expanding base of operations.

By the time they reach their junior year our elementary education majors have already taken one course in biology and two courses chosen from physics, chemistry, and geology. These are the same courses science majors take at Austin Peay. The elementary education program also requires General Science 302–303, which incorporates content in the Earth, physical, and life sciences with methods and materials of instruction for the elementary schools.

For the first half of the term the preservice teachers study curriculum design; instructional strategies; methods of assessing individual student needs, abilities, interests, and skills; techniques of evaluation, grading, and reporting student progress; and student and teacher interaction in varied learning situations. During this theory and content work at the university they also learn to develop and implement instructional materials, including learning centers, units, instructional games, learning labs, and individualized student programs.

Each student teacher is then assigned to one of the participating inservice teachers, working with that teacher and the university instructor to design and implement a unique field-based experience which meets the needs of the preservice teacher, the supervising teacher, and the students.

The preservice teachers develop skills in classroom organization, management, discipline, and record keeping. They work individually with students or with small groups. They develop materials to individualize instruction, devise labs for groups of 20 to 30 students, and establish learning centers for groups of four and five students. In addition to their experience with their assigned inservice teacher, students spend half of their class time at the elementary school in group lab situations that the university instructor facilitates. The university instructor teaches six demonstration labs during the quarter, one each in grades K–5, "borrowing" one entire classroom and group of students at each grade level. These demonstrations generally last for 50–60 minutes. A second hour of debriefing follows the lab to allow university instructors and preservice teachers to evaluate procedures, materials, and reactions of elementary students. Inservice teachers from these classrooms also participate in the labs.

Field Experience for Preservice Teachers

Field work consists of four parts: demonstration labs practice labs, materials development, and tutorials.

During demonstration labs, each preservice teacher will observe the university professor teaching an elementary science lab at every level, K-5.

During practice labs, each of the labs demonstrated by the university professor will be disseminated to the other grade levels within the school by the preservice teachers. Each preservice teacher will be assigned a partner and then the two preservice teachers will be assigned to a teacher. They will teach one of the labs demonstrated by the university instructor to their assigned class.

During materials development, each preservice teacher will develop one lab for the class assigned in cooperation with that class's inservice teacher. The lab will be implemented by the preservice teacher and evaluated by the inservice teacher.

For the tutorial section, the preservice teacher will spend two full afternoons each week in the science center at Barksdale. This time is to be used for tutoring children, working on learning centers, and doing research for the inservice teacher.

The Inservice Component

Inservice teachers derive many benefits from our needs-oriented model. The university instructors become their private science education consultants. These instructors are available to facilitate or monitor special inservices and curriculum revisions. Working with the young teachers provides professional stimulation and challenge to the Barksdale faculty. Aside from human resources, the program provides materials and equipment to make the job of teaching science easier. Preservice teachers contribute 50-60 instructional games, units, and labs during each academic year.

When several dozen inservice teachers pool resources with the university, and include parents and their resources, the possibilities for creative science instruction become all but limitless. Many of the needs inservice teachers expressed in our survey are met by Barksdale's collaboration with Austin Peay. But collaboration within the school has also been improved as a result of our program.

Most elementary teachers can testify to the general lack of coordination in grade level planning and scope and sequence planning. Fourth grade teachers might meet and plan together, and even meet with third grade teachers, but coordinated planning and decision making among K-5 science teachers is much rarer than it should be. The science center at Barksdale publishes a newsletter as one avenue of communication among the teachers. Planning for inservice training also brings the faculty together.

The faculty of the elementary school elects one representative from each grade level to serve on a curriculum committee for inservice training within the school. The committee works with the professor to identify needs and structure appropriate activities.

Our model makes efficient use of professionals and their years of teaching experience. There is no extra cost to either the university or the school.

Plans for the Future: A Regional Training Center

By the fall of 1988 we hope to have established a regional training center at Austin Peay. Featuring a lab area complete with equipment and supplies to teach all areas of the new state science curriculum, the center will be housed in the Claxton Building with a complex of offices and classrooms for professional education, and will be used by preservice and inservice teachers during training. The regional center will serve eight counties and school districts in Kentucky and Tennessee. A consortium of professors representing the disciplines of biology, chemistry, geology, physics, mathematics, and science education will serve as consultants for training.

The inservice training model, a joint project of the local school system, Austin Peay, and the state department of education, is designed to strengthen science education for students at the elementary and middle/junior high school levels. We will do this by preparing, motivating, and recognizing teachers, who are central to the motivation and learning of students, and exchanging and replicating effective teaching materials and techniques for their use. Inservice will provide an opportunity for peer teaching, leadership development, and dissemination of ideas. The project will become self sustaining after three years.

A cadre of well trained and highly skilled elementary science teachers will be identified and recruited as team leaders. These leaders will share hands-on activities, up-to-date content, teaching methods, and research in teaching and learning. Team leaders will guide and structure the training sessions for participating teachers.

Team leaders must have five years of experience with science teaching, career ladder status (granted by the state of Tennessee to two highly qualified teachers in each of the schools cooperating with this project), their principal's recommendation, and a strong interest in science. Summer training for team leaders will be financed through the career ladder program.

Inservice training for participating teachers will be conducted locally, will involve intensive hands-on activities, and will introduce teachers to the science content requirements for each grade and to recent developments in science. Teachers will have the opportunity to work with the best instructional materials, educational technology, and teaching methods related to the content of the knowledge-intensive sessions, and will have time to adapt these materials and methods for use in their own classrooms.

The inservice training will be conducted in small groups to facilitate peer support, peer tutoring, and leadership development among teachers. Initial training will be followed by 12 three-hour sessions for inservice teachers during the school year. Substitute teachers will cover classes while teachers attend these sessions.

Benefits to the Student

"Back to basics" and the record keeping it entails have temporarily robbed many science programs of their dynamism. But many of the basic skills we want to build in language arts and mathematics can be fostered through an activity-oriented, hands-on approach to curriculum development in science. We start with an emphasis on the stu-

dent as a learner, one with unique needs and interests and a unique style of learning. Hands-on involvement is the foundation for understanding facts and concepts and for building scientific generalizations. Students learn best when they are interested, active, and involved. At all times, in our program, the elementary student is the focus of concern.

The student at Barksdale has the opportunity to examine a science concept or become involved in a science activity either individually or as a part of a group. Since trained parent/community volunteers, preservice teachers, or high school science students are always in the center, a teacher has the option of sending one or more students to the center at any time during the day. An inservice teacher can reserve the center and its staffer for a particular date or time period.

The interest the science center generates is not amazing. It is natural that this would be a favorite place for students, a place where they can learn things they want to learn. Science should be exciting, for students and teachers. At Barksdale and Austin Peay, it is.

The following are examples of science center activities.

- Seven students from a fourth grade class have had a reading lesson and discussed marine life. They elect to spend 40 minutes of their independent time in the science center under the supervision of a parent volunteer. During that 40-minute period they observe the lower and higher invertebrates living in the salt water aquarium.
- Two fifth-grade boys have an interest in agriculture and plan to join the local 4-H club in the fall. One of the preservice teachers is willing to teach them the process of grafting. Their regular teacher allows them to spend an hour on two separate occasions with the preservice teacher, during which time they graft a winesap scion onto the crab apple tree in front of the school building.
- A student arrives at school at 8 o'clock with an insect in an aspirin box. Her teacher has covered the topic of insects earlier in the school year, but she wants to learn more about this particular insect. She requests the use of the science center and the assistance of the community volunteer working there on this day, in order to examine and identify the insect. The teacher gives her permission. She reports to the center during her scheduled library free time. She uses a microscope with a deep well slide so she can observe the insect while it is alive. She is helped to key the insect by the use of an elementary insect guide that she finds in the center.

Evaluation

Members of each of the role groups involved in the model–inservice teachers, preservice teachers, and elementary students—have been asked to respond to the model's ability to meet their individual needs. All have found aspects of the program valuable for their learning, and preferable to more traditional models. We are continually learning what works and enhancing it, and eliminating or modifying what does not.

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Chapter 8 Elementary Preservice Education in Science and Math

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The University of Southern Mississippi (USM) was established by an act of the Mississippi Legislature in 1910 as the Mississippi Normal College. Today USM is a comprehensive university with more than 500 full-time faculty members and an academic year enrollment of about 13,500. Our primary service area is the southern half of Mississippi. The main campus consists of 135 buildings on 254 acres of land within the city limits of Hattiesburg, population 65,000.

The primarily female student population for the preservice elementary program ranges in age from early twenties to mid-forties. A gradual upward shift in the mean age in recent years reflects a significant number of women returning to the campus to complete programs that were interrupted by marriage and the care of young children. The typical student entering the program met minimal science course requirements for graduation from high school and expresses considerable anxiety about the study and teaching of science.

Background of the Program

The incentive to restructure our science education program for preservice elementary teachers came from our involvement in the 1970s with National Science Foundation projects to assist school systems in implementing the "alphabet" curricula, BSCS, ESS, SAPA, and SCIS. Among the Mississippi teachers who participated in these projects, confident, knowledgeable, skilled teachers of science at the elementary level were found to be in short supply. Perhaps even more distressing, we found that teachers and administrators gave science teaching a low priority among the professional responsibilities of elementary school teachers. Since many of the teachers in the inservice education projects were graduates of the University of Southern Mississippi, questions arose about the quality of the existing science preparation program. We undertook a critical examination of our science content and science methods course offerings for elementary education majors.

In the early 1970s a sequence of four science content courses—two physical science and two biological science was among the core curriculum requirements for non-science majors at USM. As non-science majors, the preservice elementary teachers met this requirement. The science courses were taught in large lecture sections and supplemented with visual aids, demonstrations, films, reading assignments, and study sheets. There were no laboratories. The tests were usually short-answer in format and tended to emphasize recall of scientific information. The courses presented science as a body of knowledge found in books and heard about in lecture halls.

In sharp contrast, the science teaching methods course required in the elementary education program was taught in small sections with hands-on involvement, using materials representative of nationally recognized curricula in elementary school science. In the science methods course preservice teachers discovered strategies for teaching science totally foreign to their previous experiences in college science courses. We questioned whether a single methods course could significantly alter our students' image of science and science teaching, after years of experiencing science as a body of facts to be committed to memory. Teaching be-

havior is strongly influenced by the teacher role models a student encounters. If our elementary school teachers were to exhibit the style of open inquiry reflected in the new curricula, the science courses at USM had to reflect that pattern of teaching.

The faculty in the department of science education decided to change the science curriculum for elementary education majors. As a first step, we identified elementary education majors enrolled in the large sections of the science content sequence for nonscience majors and offered them separate small sections. This made it possible to develop curriculum materials and explore teaching approaches to meet the special needs of preservice elementary teachers. A separate science course sequence for elementary education majors was approved through the various university committees and councils in the 1974–75 academic year. The need for this program had to be convincingly articulated many times to obtain approval, in view of the additional cost of the program, the resistance of scientists who felt this course sequence might be a less rigorous treatment of content in the various disciplines, and the fairness issue involved in offering special courses in the core requirements to a limited segment of the student population.

The Project

The faculty in the department of science education committed themselves to an all-out effort to develop the best possible science program for the preparation of elementary school teachers. A preliminary proposal was developed and submitted to the National Science Foundation. NSF staff members persuaded us that the mathematics program for preservice elementary teachers must be upgraded at the same time, if we were to achieve significant improvements in scientific knowledge and process skills. Competency in mathematics appears to be inexorably linked to advancement in knowledge and understanding of science.

After a full year of planning, the department of science education, in association with the department of mathematics and the department of curriculum and instruction, submitted to the National Science Foundation a proposal to restructure the science and mathematics components of our program for preservice elementary teachers. Our project, *The Implementation of a Sequential Science and Mathematics Program for Preservice Elementary School Teachers*, (NSF Grant # EPP5719223) was funded for a three-year period beginning in July 1975, under the NSF Division of Experimental Projects and Developing Programs.

At the time we received our funding, a number of other projects were already underway to develop curriculum materials for preservice education of teachers in science and mathematics. To prevent costly duplication of effort in curriculum development, the project at USM was designed to use curriculum materials that were successful at other institutions and test their transferability. Prior to the USM project, there had been little, if any, coordinated effort to restructure both the science and mathematics components of a teacher education program throughout an institution. Most previous programs had been for small pilot groups of preservice elementary teachers, rather than an institution's entire population of teachers in training.

The science and mathematics preparatory program that emerged from the three years of intense NSF project activity remains basically intact, with the same general philosophy, goals, and teaching approach. Some modifications have been made in the curriculum materials, and changes have occurred in teaching personnel. To adhere to the criteria of the Search for Excellence in Science Education, this description of the current program has been limited to the science component of USM's preservice elementary education program.

Our Current Program

The philosophy of our preservice program for elementary teachers is grounded in our concept of the nature of science, the way children learn, and the goals of an elementary science curriculum. We view science itself as a search for patterns that requires the active involvement of the learner. Children are natural inquirers, who continually try to make sense of the world around them by gathering information and processing it into patterns or regularities. Therefore, exemplary science programs for the elementary grades should emphasize the investigative nature of science.

The goals for elementary school science should be to develop

- An understanding of the major concepts which are the foundation of modern scientific thought
- The science process skills necessary for continued self-learning
- An understanding of science and its societal implications

For our teacher education program this philosophy dictates inquiry-based, activity-centered instruction which involves preservice teachers in the various processes of science as a means of discovering significant scientific concepts for themselves.

We further believe that preservice teachers will model in their own science teaching the behaviors of their former science teachers. Preservice teachers who experience inquiry-based, activity-centered instruction under the tutelage of exemplary role models are likely to exhibit teaching behaviors which reflect the nature of science, relate to the goals of elementary school science, and show sensitivity to children as learners.

Goals of the Program

The program's goal is to produce knowledgeable, skilled, confident teachers committed to improving the teaching of elementary school science. In behavioral terms, the teachers who complete the program should be able to

- Show levels of achievement in science content and process skills adequate for teaching elementary school science
- Demonstrate, in classroom teaching situations, inquiry-based, activity-centered instructional skills
- Match teaching objectives and approaches to the needs of children as learners
- Exhibit confidence and enthusiasm about teaching science

Nature of the Program

The preservice science program is comprised of four content science courses—two physical science and two biological—followed by a science methods course. The 12 semester-hour content and three-hour methods requirements add up to a 15 semester-hour science program.

The content courses focus on developing the knowledge

and process skills to teach current exemplary science programs for the elementary grades. Each course integrates content and teaching methodology in the sense that the course instructors serve as role models for teaching behaviors. All courses are taught in a laboratory setting. That is, prospective teachers are taught with materials which allow for direct experience in activity-centered investigations aimed at developing basic concepts and skills. Faculty make a concerted effort to reduce anxiety toward studying and teaching science by providing for successful experiences.

The fifth course in the science sequence is predominantly a course in methods and materials for teaching elementary school science. The course is organized in three major parts. Part one provides conceptual background related to the meaning of science, the goals of an elementary science curriculum, the process and content aspects of learning activities, and the characteristics of the young learner. Part two focuses on the development of instructional skills by examining different teaching strategies. Since experimenting as a teaching strategy seems to be the most difficult to master, we emphasize integrated process skills and the use of experiments in the classroom. A science fair day is a component of this part. Each preservice teacher completes an experiment and submits a written report, science fair display, and log book for the competition.

Part three involves the preservice teachers in the preparation and supervised teaching of six science lessons, each approximately 50 minutes long. The six lessons focus on a single unit theme and are usually adaptations from nationally recognized science curricula. Thus, this course not only addresses methods and materials of teaching but also provides practical experience in applying science content in actual classroom settings.

Materials and Curriculum

Our curriculum has been continuously examined and modified since the program restructuring during 1975–77. Curriculum materials developed by Arnold Arons at the University of Washington and his textbook *The Various Language: An Inquiry Approach To The Physical Sciences* were used in the physical science sequence for several years. Many of the activities in Arons' program continue to be used, but new ones have been adopted from other sources and developed in our own program.

The biological science courses used materials developed as part of the Purdue University project, *An Integrated Approach To The Science Preparation of Prospective Elementary Teachers*. The Purdue project was funded by NSF under the Undergraduate Preservice Teacher Education Program. Purdue activities were essentially adapted from the BSCS Green Version biology program and the Science Curriculum Improvement Study.

Science textbooks which reflect the philosophy and teaching approach we want for our preservice elementary teachers are not available for the college level. Arons' book, for example, emphasized the development of mathematical reasoning and interpretive skills, but did not develop many of the science concepts that the preservice teachers will be expected to teach elementary students. At present we are using several textbooks, materials from the national curriculum projects, and other materials developed by the professors who teach our courses.

The courses are scheduled as three semester hours lecture and one semester hour laboratory; however, the teaching emphasizes direct involvement of the students in activities which lead to discovery of ideas and relationships. There is seldom a full period of formal lecture; instead there are frequent discussion periods when students share and interpret results under the skillful guidance of the course instructor.

We use well-written physical science and biological science textbooks for reading assignments to reinforce and extend the classroom activities. Most college students have been conditioned by past educational experiences to approach learning through the printed word, so we try to capitalize on this established learning style to help them build a strong foundation of scientific knowledge. We choose books which give clear explanations and offer illustrations, data, charts, and graphs to be interpreted. In the courses, we try to expose the preservice teachers to many teaching strategies and help them to see reading as just one means of approaching the study of science. We try to make them aware that children need to experience science directly, not just read and talk about it.

The basic textbook for the science methods course is *Exploring Science In The Elementary School* by Donald Kauchak and Paul Eggen. The authors share our goals for elementary school science, and our understanding of the nature of science, how children learn, and the ideal strategies for teaching science.

In the field experience component of this course, lessons are usually adapted from various curriculum projects, with the preservice teachers responsible for finalizing the plans and practicing the lessons before actually teaching small groups of children. We try to assure that the experience of working with children is successful and provides students with positive feedback about themselves as teachers of science.

A resource center housing instructional materials for the K-college levels was established with NSF project funding. The resource center is a support facility for both the undergraduate and graduate level programs administered by the department of science education. The center includes a wide range of current instructional materials:

- complete sets of programs, such as *Developing Mathematical Processes, Science Curriculum Improvement Study,* and *Science—A Process Approach*
- Science textbook series
- Metric teaching aids
- Films, filmstrips, and other audio-visual aids
- Manipulative laboratory materials for classroom use
- Sourcebooks of teaching activities and games
- Sample instruments for assessing content knowledge, attitude, and skill development in science
- Microcomputers and computer software

The preservice teachers use this facility in completing course assignments and as a source of materials for their student teaching experience. The center plays a critical role in introducing preservice teachers to the use of computers in teaching and learning.

The Role of the Professor

The professors for the courses in the science sequence are expected to exemplify good practices in planning, teach-

ing, and evaluating. They model strategies for teaching, assuming the roles of motivator, counselor, guide, initiator, discussion leader, resource person, lecturer, demonstrator, questioner, evaluator, and others appropriate to the various strategies. We feel it is important to alternate among a variety of methods, matching teaching objectives to the students' needs, the materials that are available, and the content/process goals.

Since many preservice elementary teachers are anxious about studying and teaching science, building positive self-concepts about their ability to learn and teach science is a major responsibility of the program. This means that each student must be respected as an individual of dignity and worth, and never demeaned or belittled. The classroom environment has to be one of openness and acceptance where students feel comfortable asking questions and expressing ideas.

The Role of the Student

Our preservice elementary teachers are active participants in the learning process, rather than passive receivers of information. They are investigators searching for patterns and regularities they can use to describe and explain phenomena in the natural world. They are encouraged to question: "How do we know...? What is the evidence for...? How could we explain...? How could we test?..." As students, they are encouraged to show initiative, curiosity, and the desire to find out for themselves.

Evaluation

Evaluation of Students

For the four science content courses, student achievement is evaluated on the basis of teacher-made tests, written reports of investigations, and other assignments. In testing, emphasis is placed on higher-order cognitive levels, with students being asked to explain, compare, describe, interpret, and evaluate. Some test items are short answer and require recall of information or comprehension; however, essay questions requiring analysis, synthesis, application, and evaluation tend to predominate.

In evaluating student achievement for the methods course we consider teacher-made tests, ratings of teaching performance, science fair projects, written reports of interviews based on Piaget's tasks, and lesson plans. Rating criteria vary with the assignments.

Evaluation of Program

During the initial restructuring of the program, supported by NSF funding, an extensive formative and summative evaluation was conducted. Data collection continues to the present time. Students use rating scales to evaluate the course instructors. We solicit feedback from students in writing and through interviews regarding course content and teaching approaches. Testing is keyed to course objectives. Test results are examined and courses are revised when we find a better way to meet the course objectives.

Faculty members teaching courses in the sequence meet formally to discuss the curriculum and ways of improving the sequence. In addition, they informally share new activities being tried, problem areas, and successes and failures in teaching. The faculty works as a supportive team constantly striving to improve the course sequence.

In 1985 the program was reviewed by the curriculum committee in the College of Science and Technology, the curriculum committee for the College of Education and Psychology, and the Academic Council of USM. The four-course science sequence was approved by these committees to meet the core requirements for elementary education majors. We are proud that the program continues to be viable ten years after the initial grant funding and is accepted by the academic community on our own campus.

Our program, when examined against the criteria for excellence, shows many strengths. The following is a partial list.

- Evaluation data demonstrate that the program develops positive attitudes toward science and science teaching.
- The program requires twelve semester hours of science content, including broad treatment of physical science and biology, and limited Earth and space science topics.
- The content and methodology in the courses are applicable to sound elementary school science programs. Both the science content and methods courses use the problem solving processes of science, such as observing, classifying, measuring, interpreting data, and experimenting. Field and laboratory activities are integrated in science content study.
- Societal implications of science and technology are addressed in the courses. For example, if a field trip to a local electric power plant is a part of an electricity unit, students will examine the environmental technology used in the plant to prevent air and water pollution. The nuclear waste issue is studied in relation to the Mississippi salt domes, which are presently being considered as sites for a depository. Genetic engineering, population control, energy consumption, and other topics with societal implications are also explored.
- We require three semester hours of science teaching methods with a field-based teaching component. The field experience involves hands-on problem solving and skill development activities.
- Microcomputers and other current technology used in the science content and methods course provide experience with the use of these tools in concept/skill development.
- The program meets all the criteria for excellence with regard to faculty characteristics. The faculty members are well qualified, experienced, competent teachers. Each has experience in teaching science in the public schools. They are active in professional associations and work closely with the Mississippi Department of Education and the state public school systems. They encourage and model participation in professional organizations and research involvement.
- Science teaching resources include well-equipped laboratory facilities, a resource center with an extensive collection of curriculum materials, source books, manipulative aids, visual aids, computer software, microcomputers, television monitor and cassette player, microfiche reader/printer, and more. Library holdings exceed 30,000 volumes related to the program, plus a considerable collection of children's science tradebooks.

Weaknesses of the program, examined against the criteria for excellence, include the following.

- The present four-course content sequence needs to in-

corporate more Earth science. Observational astronomy, the water cycle, the carbon dioxide/oxygen cycle, weather, and other topics do receive some treatment in the course sequence, but we plan to develop a separate Earth and environmental course.

- In the science methods course some hard choices have been made because there is never time to treat all areas. One such choice relates to developing skill in writing lesson plans, teacher-made tests, and other teaching materials. We are aware that preservice teachers need help in planning science lessons and would like to incorporate more of this activity in the methods course, but lesson planning is heavily emphasized in other methods courses. In an effort to assure that the field experience in science involves hands-on, exemplary activities with which the preservice teachers will experience success, our course professors have assumed the major responsibility for planning the lessons so far. Lessons adapted from various curriculum projects are offered as exemplary materials. From the exemplary lessons, students can begin to see how science should be taught and develop the confidence to try constructing their own materials later.
- We need more extensive ongoing evaluation of the program to provide continuous feedback for future modifications. We recognize the need, but with the present faculty workload we have been unable to accomplish this to our satisfaction.
- Mississippi has an extensive junior college system. Approximately 60–70 percent of the students in teacher education are transfers from the junior colleges. Because we accept transfer credits in laboratory science to meet our core requirements, many graduates in the elementary education program have not completed the four-course science sequence offered at USM.

Program Maintenance Needs, Human and Financial

The key ingredient in the success of our program is role modeling by the teachers of each course in the sequence. Since administration and teaching of the program are the responsibility of the department of science education, it has been possible to be very selective in assigning faculty to teach the courses in the sequence. The coordinator for the preservice elementary science program, Iva D. Brown, works with the chair of the department of science education, Bobby N. Irby, in identifying faculty whose teaching philosophy agrees with that of the program. Faculty involved in the program are professionally active in promoting science education and have records of proven performance in the classroom.

The science resource center is an essential support facility for the program. It costs money to staff the center and to keep its resources current.

Laboratory facilities with basic equipment are required for teaching the physical science and biological science courses. The science teaching methods course requires a wide variety of materials suited to the teaching of elementary school science, in quantities sufficient for teaching about two hundred children, and funds for replacing expendable items.

We struggle to keep the program as cost-efficient as possible. Clearly this program is more expensive to operate than a comparable sequence of lecture courses. But the university continues to sustain it, which indicates that we must be giving good value.

Future Changes In The Program

The Mississippi Board of Trustees for Institutions of Higher Learning maintains an ongoing program review process. The board mandated last year that eight semester hours of laboratory science be required in the core at all public colleges and universities. In a separate but related action, they increased the number of high school credits in science and mathematics required for entrance to state colleges and universities. The courses in the four-course science content sequence, which each formerly carried three semester hours of credit, must now be offered as four-credit courses (three hours lecture and one hour lab) to meet core requirements. With this change, the classes in the four-course sequence total 16 semester hours. Since elementary education majors are still only asked to take 12 hours of science, teaching students may satisfy the requirement with just three courses.

We are planning to restructure the sequence into three courses—physical science, Earth and environmental science, and life science. The basic philosophy and approach will not change, nor will the total number of hours required. The content of all courses will need to be reviewed and modified.

Other impending changes are linked to the Education Reform Act passed by the Mississippi Legislature in 1982. Certification requirements for teachers and accreditation standards for teacher education institutions are being reviewed and new guidelines established. Our science methods course will evolve to align with the competencies identified in the Georgia Department of Education plan for performance-based certification, which has been adopted by the Mississippi Department of Education. Experiences will have to be built into the elementary education program directed toward achieving the specified competencies. For example, the Georgia plan emphasizes competency in planning and organizing materials for instruction. To meet the performance levels in this area we will have to devote more time and effort to writing behavioral objectives, developing compatible teaching procedures, and designing evaluation instruments.

Our goal for the future is a totally field-based science methods course, with professors and preservice teachers meeting classes in a public school setting and working with children as they study various instructional approaches.

Chapter 9 Excellence in Preservice Elementary Teacher Education in Science: What We Have Learned

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The ultimate purpose of the Search for Excellence in Science Education (SESE) is to provide inspiration and guidance to those who want to improve the quality and quantity of science taught in America's precollege institutions. Characteristics of good science programs and appropriate amounts of science were spelled out in Project Synthesis' desired state. The goal of precollege science teaching is to produce citizens who are scientifically and technologically literate: who know enough about the scientific enterprise to make reasoned decisions at the personal and societal levels, take full advantage of their academic opportunities, and function effectively in a wide range of careers in tomorrow's scientific and technological society.

Can preservice teacher education in science help to produce such citizens? We believe it can. Both positive and negative evidence supports our belief. As positive evidence, the teachers who developed the SESE exemplary elementary school science programs reported that the inspiration to develop their excellent programs came from courses or workshops they had taken. As negative evidence, elementary teachers other than those in exemplary programs frequently ascribe a major part of their science anxiety to a lack of adequate preservice training in science. School administrators share that perception.

The characteristics of the desired state, for preservice elementary programs that will enable teachers to promote scientific and technological literacy, were enumerated in the first chapter. But a review of the applications for the current search suggests that many professionals in teacher education are not familiar with the SESE criteria. Consequently, it is necessary to underline the distinction between the elementary science curricula which were developed with federal funding during the 60s and 70s, the so-called "new" curricula, and the exemplary elementary science programs envisioned by Project Synthesis and exemplified by the honorees of the Search for Excellence in Science Education. Educating prospective teachers for the latter is the current goal for today's preservice elementary teacher education programs.

The application forms used for this search for excellence were the same as those for searches in the other fields of precollege science education. Data were limited to the descriptions of the programs supplied by the institutions themselves. Due to a lack of funds, there were no site visits. Although the only meaningful indicator of an excellent preservice program is the success the teachers have with children in schools, the search application did not require information about the performance of preservice teachers once they were employed by school districts. Several of the exemplary programs do monitor their own graduates, but we did not accumulate data on the comparative effectiveness of these graduates and those from more traditional programs.

Each program in the preceding chapters was selected because of its noteworthy progress toward the desired state. If the commendable attributes of all these exemplars were combined, we would see a model approaching the desired state for preservice elementary teacher education in science. No one of the programs by itself is a model of the desired state.

The following is a synthesis of what has been learned

from this search. The names of institutions noted in parentheses direct the reader to at least one example of each observation. The examples in the parentheses, however, are not intended to indicate an ideal state in any area.

Insights Gleaned From This Search

The commonality among the exemplars suggests that one of the things most essential to the development of an excellent program is vital links among the many people and groups who share an interest in science teaching. Some useful interfaces appear to be between

- Science educators and natural scientists
- Science educators, natural scientists, technologists, and social scientists
- Science educators and the community, e.g. business and industry and civic groups
- The university program leader, faculty, and prospective teachers, and elementary school administrators, teachers, and students
- Science educators and the state education agency
- Science educators and foundations interested in education

A program's problem-solving capacity will be enhanced by the variety and fruitfulness of its interfaces, and so will its ability to meet the SESE criteria. Multiple interfaces provide a rich and varied data base which can make current information from a variety of perspectives available for decision making. New strategies based on this data can offer new solutions to program problems. A program cannot but benefit from the synergism that results from networking.

Each of the preceding exemplars could continue its progress toward the desired state by increasing the number of interfaces that support its program. Since the role of a science educator is to be a link among scientists, and between scientists and the rest of a community, it is reasonable to expect the science educators on a college faculty to design and maintain networking strategies. The first step will be to persuade the individuals involved of the benefits each can obtain from investing in the collaboration.

Before attempting to make specific changes in a program, the persons spearheading the development and maintenance of these interfaces need to develop a common vocabulary and context for communication, leading to a common set of assumptions upon which the group will build. This minimizes potential for miscommunication, and thus builds up the trust essential to any collaborative venture. Then a group philosophy, goals, and the specific tasks to alter a program can be addressed.

Excellent Program: Cross Department Boundaries

The interface between science educators and natural scientists is critical to providing preservice teachers with current content that is applicable to the elementary science curriculum. Decisions about what part of the accrued body of science knowledge is appropriate for preservice teachers and how it should be taught are best made collaboratively. Faculty whose primary research and subsequent expertise are in science education know the goals for elementary science teaching and the capacity of elementary learners. Faculty whose research and expertise are in one of the natural sciences know the directions and the cutting edge of work in that science. Together, they can develop creative approaches to educating preservice elementary teachers whose students will be adults in the twenty-first century.

Two models of collaboration between science education and natural science were illustrated by the exemplars. In one, the science educators have academic appointments in a natural science department or college (Ball State University and Eastern Michigan University). In the second, science educators have academic appointments in departments or colleges of education and collaborate with faculty in the natural sciences either individually (Austin Peay State University) or through cross-unit committees or councils (University of Southern Mississippi, University of Toledo, Utah State University). A third model, not described by any of the exemplars, gives a faculty member dual appointment, half time in a natural science department and half time in a college or department of education. Success appears to require an ongoing formalized relationship between scientists and science educators. Faculty provide periodic feedback to a permanent group responsible for program improvement, while implementing decisions made by the group. Communication does not stop once the group agrees to program changes.

Even though the success of an educational endeavor depends on the individual teacher, individual excellence cannot insure that program innovations will become permanently incorporated in an institution. Having a committee or council may seem unnecessary when there is a strong individual relationship between a science educator and one or more natural scientists, but there are vital roles such a formal structure can play to insure excellence in the long run.

- A cross-disciplinary group can expedite program changes through the multiple stages the curriculum process requires in a large university.
- Even if personnel in the institution change, a council provides continuity.
- If individuals have a personal falling out, the council remains to continue tending to the program.
- If people beyond the first interactors wish to get involved, they can approach a council through known procedures more easily than they can intervene in a one-to-one relationship.

Within the College of Arts and Sciences at Eastern Michigan University, four science departments have joined for ongoing planning, review, and revision of their program. Ball State University has a science and mathematics resource advisory team representing the College of Science and Humanities and the Teachers College. Utah State University has an advisory committee coordinating College of Education and College of Science faculty who develop science courses for the preservice elementary program.

Councils should be structured to obtain input from outside the group, and have potential for inviting new people to participate as uses for other areas of expertise appear.

A uniqueness of the University of Toledo is that it has a specific structure to enhance the interface between science educators and faculty in educational psychology and other foundational fields. Teaching teams from Educational Psychology, Curriculum and Methodology, Educational Media and Technology, and Social Foundations of Education meet in weekly planning sessions. Team leaders meet with col-

lege administrators to evaluate the effectiveness of team plans.

Links to State Agencies are Vital

The interface between university science educators and state education agencies is critical to the quality of preservice elementary teacher education programs. Many states are currently examining their teacher certification criteria. Others will surely follow the example of those who have already drastically altered their certification procedures.

Commonly, graduation requirements in college and university teacher education programs go beyond state certification requirements. This may change, as more states strive to make *certified* synonymous with *qualified*.

Universities commonly respond to changes in state certification requirements by making the state's requirements a framework for their preservice programs. We recommend a more active strategy. First, design an optimum program based on the SESE Criteria for Excellence in Preservice Elementary Teacher Education in Science, using research on effective science teaching in elementary schools and what teachers say they wish they had learned as undergraduates. Then modify the optimum program by adding or altering as necessary to meet the state certification requirements.

Hopefully, interfaces between educators and state education agencies will insure that forthcoming elementary teacher certification requirements reflect the SESE criteria. If this is not the case, it will be up to science educators to advocate that their states change the requirements, rather than adjusting university programs to meet undesirable requirements.

University programs are influenced not only by state certification requirements, but also by the needs and wishes of cooperating school districts, faculty perspectives and organizational needs within the university, and the perceived needs of prospective teachers in the target audience. All of these need to be considered in designing a program.

Creative Course Design Promotes Excellence

The exemplars deliver science content either through courses specifically designed for, and limited to, prospective elementary teachers (University of Southern Mississippi, Ball State University, University of Georgia) or through standard university courses with sections reserved specifically for preservice elementary teachers (Utah State University). Three variations on the latter might be

- Prospective teachers sit in large group lectures with other students and separate into small groups for discussion and lab work
- The course is the same, but prospective teachers are taught in small classes, while other students learn in large lecture halls
- The course labels are the same for all students, but the content of preservice teacher sections is tailored to teachers' needs

A composite of the characteristics of the science courses in the exemplars includes

- Experience with materials suitable for use in elementary schools (University of Georgia)
- Focus on process skills (Eastern Michigan University)
- The teaching of science methods mixed with the teaching of science content (Eastern Michigan University)
- Instructors modeling good teaching (all of the programs selected)
- Team teaching by science educators (University of Georgia, University of Southern Mississippi) or science educators and scientists teaching together (Utah State University).

In addition to being a most effective instructional strategy, integrating the teaching of science methods with the teaching of science content, as is done at Eastern Michigan, economizes program time, making room to study additional topics.

Two of the program strengths exhibited by all the exemplars were their training in the processes of science (observing, classifying, measuring, interpreting, predicting, and experimenting) and their incorporation of the biological, physical, and Earth sciences. However, the Earth sciences appear to need more attention before we will have attained a balance among all the disciplines, even in these exemplary programs.

Excellent Programs Integrate Science, Technology, and Society

Overall, there is still a need to develop procedures which provide prospective teachers with a significant understanding of the societal implications of science and technology (S/T/S). All the programs reported that they attend to S/T/S, but there was little to provide guidance to the reader on ways to do it.

Developing two related interfaces would contribute to significant S/T/S education. They are the interfaces among science educators, natural scientists, technologists, and social scientists, and those between the science educator and the community. These links will allow inservice teachers to use the contacts they made during their undergraduate years to obtain S/T/S resources, including human expertise, equipment, printed materials, media, and access to physical sites away from school. Since teachers cannot become experts in all the disciplines, and schools usually have limited budgets for science equipment, programs need to use the community as a resource for teaching science in the classroom and outside the school.

Community volunteers can supervise children, guide children through learning center activities, and help teachers develop expertise on a topic (Austin Peay). Field sites, such as an electric power plant (University of Southern Mississippi), or a dairy farm and a weather station (Ball State) highlight the relevance of teaching basic science and technology.

Excellent Programs Stress Safety

Provisions to teach an understanding of how to ensure safety when teaching science were conspicuous by their absence from these programs. Ball State and Utah State were the only schools whose reports even mentioned the need for classroom safety training.

Excellent Programs Build Positive Attitudes

Success experiences built into undergraduate programs appear to be the key to mitigating science anxiety and assuring that preservice science teachers will have positive attitudes toward teaching science. The potential for success experiences can be increased by developing a degree of

individualization in courses and programs, matching requirements to students' backgrounds and needs (Utah State University).

Prospective teachers can experience success when they are given a relatively safe environment in which to take risks, be creative, and try their own ideas in designing a science investigation (Ball State University). Opportunities for experiential learning increase potential for success, and help teachers understand the importance of hands-on teaching in elementary science. They overcome anxiety when they use simple laboratory materials that are in the average school already, or can be purchased inexpensively or collected from home (Eastern Michigan University).

Another way to create successful experiences for preservice teachers is to teach science in a context that makes its concepts relevant to the learner. Emphasizing relationships among the sciences, S/T/S, and human values makes science relevant. When science is meaningful it is perceived as easier to understand. Prospective teachers learn more. Perceiving themselves as successful learners of science builds their self-confidence, which contributes to a positive attitude toward teaching science.

Providing early field-based experiences with science teaching is still another way to build positive attitudes (University of Toledo). The experience of these exemplars suggests the value of teaching prospective teachers to teach in incremental steps—beginning with cognitive information about an instructional technique, sampling its use by teaching one's peers in the safety of the college classroom, and then using the technique to instruct children in schools.

Excellent Programs Provide Early and Continuous Experience with Children

The interface between an institution of higher education (IHE) and the local school districts facilitates

- Improvement in the school districts' elementary science programs
- Opportunities throughout the college program to teach science to children in schools
- Student teaching which includes experience in both planning and teaching science to elementary school students

The University of Toledo and Austin Peay State University both deliberately design their teacher education programs to serve as change strategies for improvement in their cooperating schools. Austin Peay's particular contribution is the school-site science center, a model for a formal structure to enhance relationships between a university and a school district. It provides opportunities for a variety of interactions among the IHE professor, preservice teachers, inservice teachers, children in school, and community volunteers. Prospective teachers learn to perform even in settings that are not equipped with ideal apparatus, as they and their peers generate materials for the center This model also addresses the preservice teacher's need for a transition to full time teaching by creating a continuum from preservice to inservice education.

Utah State University has structured a permanent planning committee to guide its portal school, composed of university faculty members, teachers, principals, and representatives of the university laboratory school.

In traditional programs, preservice teachers have their first contact with students in their third undergraduate year. Many universities also have a significant number of students who began their college careers in two-year institutions, with no opportunity for student teaching experience. An outstanding feature of the exemplary programs at the University of Toledo, Utah State University, and Ball State is that prospective teachers begin interacting with children in schools during their first year of college.

Excellent Programs Convert Research into Practice

Features unique to the University of Georgia are the significant number of highly productive science education researchers and their capacity for translating r... h into practice to improve science teacher education.

Excellent Programs Have Excellent Faculties

Since teachers teach as they were taught, it is essential that the people who teach science to preservice teachers model desirable behaviors. Then, the analysis of the instructor's teaching can be an integral part of science information.

Faculty at each of the exemplary institutions have experience in teaching precollege science and interest in providing high quality instruction. While some faculty have access to well-equipped resource centers on campus (University of Georgia, Eastern Michigan University) and others use facilities in local school districts (Austin Peay State University), they all model e: nplary teaching and professional behaviors.

Looking To The Future. . .

As science educators, we need to continue to develop programs which reflect the SESE criteria for teaching science in the elementary grades, and ensure that prospective teachers

- Gain the necessary pedagogical, scientific, and technological skills and knowledge
- Function effectively in settings ranging from those with fine current materials, equipment, and laboratory aides to those that lack proper support
- Can adjust creatively to the changes in science teaching that will be required of them throughout their careers in the classroom
- Are, themselves, adults who function as reasoning, decision-making citizens in this scientific and technological society

One caution is in order. In our zeal to move forward in response to the demands of rapid change, we must be judicious and not "throw the baby out with the bath water." That which experience has shown to be of value should be retained. We will, for example, continue to teach process skills, while seeking bold new approaches.

As these exemplars and those who follow their example attain the desired state for preservice elementary teacher education in science, we will be meeting the need to improve the quality and quantity of science children learn in the elementary schools of our nation. Prospective teachers will be willing and able to meet the challenge of preparing their students for the dramatically different world those students will inhabit as adults in the twenty-first century.